EXPERIMENTAL WIRELESS
& The WIRELESS ENGINEER

VOLUME
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Experimental Wireless
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Experimental Topics.

About Ourselves.

WE make no apology for adding one more to the list of wireless publications already in the field. The development of wireless achievement during the past two or three years has been so rapid and so extensive that it has become increasingly difficult for any one paper to cater adequately for each and every section of the varied interests concerned. In wireless, as in other spheres of technical interest, the need for specialised papers is bound to arise. We enter the field in no competitive spirit in regard to our contemporaries, and, as will be seen in a subsequent Editorial note, we gladly acknowledge the good work they have done. But we believe that there is now not only room, but a distinct need, for a specialist paper dealing exclusively with the interests of the serious experimenter. This is the gap which we aim to fill with EXPERIMENTAL WIRELESS. A glance through the pages of this number will indicate the general lines on which we propose to work, and in subsequent issues our programme will be more fully developed as space permits. It will be observed that we confine our contents strictly to subjects of experimental interest. The exclusion of more general matters, such as broadcasting news, elementary theory, the construction of simple home-made sets, and society reports, enable us to give the experimenter an unusual number of articles of direct interest and service to him, and this will be the main justification for our existence.

We ask our readers to reserve a final judgment on the fulfilment of our programme till they have seen our futher development during the next few months.

An Independent Policy.

An essential feature of any journal which takes for its platform the advancement of experimental science is that it should preserve a complete independence. Independence does not mean antagonism, it means freedom to help every legitimate project for the advancement of the science of wireless. By being the official organ of no society we can help all; by owing no allegiance to any trade interest we can contribute freely to the advancement of the whole industry. Incidentally we may, perhaps, emphasise the importance of the experimenter to the industry. No branch of scientific research to-day is so full of possibilities as is wireless, and the future of the industry is largely wrapped up in the improvements and new discoveries which will result from experimental work during the next decade. It is of the utmost importance to the trade that not only should they carry out research work themselves, but that they should encourage and follow the work of the skilled amateur.

The Field for Experimental Work.

In spite of the enormous strides which have been made in recent years, wireless is, to use a hackneyed phrase, "still in its infancy." Wireless telegraphy and tele-

phony are naturally the best known and most widely used examples of the radio-transmission of energy, but the future holds many developments in its keeping. Wireless control of mechanism at a distance is a branch of the science in which steady progress is being made. The wireless transmission of pictures will be followed by the transmission of scenes from life, and the wireless distribution of light and power are dreams of the engineer which are well within the bounds of possibility. The field for experiment is boundless, and though the experimenter of to-day may, in general, be content to limit his research to improvements in the transmission of speech, his horizon will steadily grow broader and broader as the years go on. The outlook and the scope of EXPERIMENTAL WIRELESS will expand in like degree.

A Word to Societies.

We have already remarked on the absence of reports of the doings of wireless societies from our pages. We exclude them in no feeling of unfriendliness; we are staunch believers in the good work societies are doing, and we wish them all an increasing measure of usefulness and strength. But their doings already receive such a generous share of space in the columns of our contemporaries that we feel they have no real need of a like hospitality from us. While, however, we do not feel called upon to report the ordinary comings and goings of society life, it is more than possible that here and there papers will be read, or demonstrations will be given, of great interest to the experimenter. Such matter when forthcoming will, we need hardly say, always receive a warm Editorial welcome from us.

Experimental Work Abroad.

Arrangements have been made whereby our readers will be kept in touch with experimental practice in all parts of the world, since we have a number of foreign representatives who will forward from time to time a summary of the march of progress in their own specific areas. Month by month we shall publish a bibliography of the more important articles which have appeared in British and foreign publications. The "Trend of Invention" will summarise the progress of wireless at home, particularly in relation to the work of the experimenter, and we shall duly record the advent of any inventions of importance which may be made abroad. By observing the directions in which patentees are working, our readers may find valuable hints for the guidance of their own efforts.

Mathematics and Wireless.

The introduction of mathematics into an article relating to wireless subjects seems to have the effect of frightening many experimenters whose mathematical qualifications are not very high. It is unnecessary to point out that little advance can be made in many directions without the aid of mathematics, but in order that the non-mathematical reader may not be unduly alarmed, we propose, as far as possible, to place all mathematical proofs and determinations in an appendix to each article where such proofs are required. There are, however, certain articles—such, for example, as "The Maintenance of High-Frequency Oscillations," by Mr. E. W. B. Gill, appearing on page 5 of this issue—which will not lend themselves to this treatment. Mr. Gill has much to say that is of direct interest to the experimenter, apart from the calculations he gives, and we hope, therefore, that the non-mathematical reader will give his important contribution the careful attention its subject warrants.

How Readers Can Help.

The large section of the wireless public engaged in experimental and research work includes people of a very widely varying degree of experience and technical attainment. For this reason it is impossible to make the contents of EXPERIMENTAL WIRELESS of equal interest to every reader, but we have endeavoured to provide in our first issue a sufficiently varied range of matter to please the majority. We shall, however, appreciate the friendly co-operation of our readers in making our journal as useful as possible to the serious experimenter, and shall be grateful for any criticisms or suggestions which will help in this direction. The first issue of any paper is never completely representative of its intended scope. We have several additional features of interest we propose to incorporate as time progresses, but meanwhile we shall be glad to receive and to consider very carefully any comments

our readers may be good enough to send us. We hope also that readers will avail themselves of our columns for the discussion of subjects and the contribution of information of immediate interest to all experimenters. A most interesting feature, for example, both to the transmitter and the receiver, will be the publication of lists of calls which have been logged. There is little use, however, in considering those of which the distance of transmission is less than about 60 miles, and in order that the lists may be of some practical value they should bear the date, time and strength of reception, together with data concerning the receiver. Records of long-distance or "DX" work is obviously of very great value, and it is hoped that readers will co-operate by compiling useful logs and sending them to us.

The Press and the Industry.

Having outlined our own policy as a new arrival in the field of wireless publications, it may not be out of place if we say a few words about the relationship between the wireless press generally and the industry. We are prompted to do this because one manufacturing firm has intimated to us that there are already too many wireless papers, and some of them "would have to be eliminated in the near future." We say unhesitatingly that publicity is the life-blood of any industry. By the word publicity we do not mean merely advertising. We mean that every industry must have a press to record the progress of discovery and invention, to disseminate the news of the industry, to focus opinion and experience, and to provide a common forum where the thousand and one problems of the industry, commercial as well as technical, may be ventilated and discussed. Moreover, every industry needs a press to tell the world what it is doing, to arouse new and increased interest in its products, and to expand its markets. This is true of any industry, but it is especially true of a new industry, as in the case of wireless. Where would the wireless industry have been to-day if it had had no press to broadcast the wonders of wireless achievement, and to bring home to hundreds of thousands of people the possibilities of practical service, as well as of private entertainment, which wireless equipment could give them? The wireless industry has been peculiarly fortunate in the enthusiastic and enterprising press which has grown up with it, and we confidently assert that all firms who are engaged in the manufacture and sale of wireless equipment owe a debt of gratitude, possibly greater than they realise, to those publishers and editors of wireless and other papers who during the past few years have done so much to make wireless communication a subject of national interest and enjoyment. Whether there are too many papers, and whether any papers need "eliminating" is a question which will automatically settle itself. When any paper fails to hold its public it will die a natural death, because no publisher can afford to continue to produce a paper which the public will not buy. But so long as any paper can maintain its reader-interest it is doing good work for the industry it represents, and should be regarded as a valuable asset rather than as a parasite to be "eliminated."

The Need for Greater Amateur Co-operation.

That the condition of the amateur movement is critical is, unfortunately, only too true. A brief survey of the correspondence columns of the various wireless periodicals reveals a vast amount of dissatisfaction in all directions. Members are not in agreement with their societies, and one society is antagonistic to another. In many cases the trouble is due to nothing more than petty jealousy, on which we need not comment; but, on the other hand, there are undoubtedly reasonable grounds for complaint in some directions. Dissatisfaction seems to arise owing to the great variation in the technical knowledge of the members of the various societies. The more advanced experimenter is too prone to forget that there was once a time when his own knowledge of wireless was very slight, and because his society is not able to provide a programme of an advanced nature he becomes discontented. The obvious remedy is for experimenters to associate themselves according to their qualifications, and we should be glad to see some effort made in this direction. Societies and associations, too, would do well to consider their relationship with others of a greater or less degree of importance, and endeavour to co-operate rather than compete with each other, to the

benefit of the amateur movement in general. It must be remembered that every amateur experimenter, whatever may be his qualifications, is dependent upon the Post Office for authority to continue his investigations. Nothing can be more prejudicial to the granting of his requests than great diversity of opinion amongst experimenters in general. There is no more convincing argument than that of a large majority, and until all amateurs are agreed it is unreasonable to expect the Postmaster-General to listen to their requests. Agreement can only result from co-operation, and it is to be hoped that the amateur movement will take steps to place itself on a firmer and more united basis in the very near future.

The "Experimental Wireless" Laboratory.

Many experimenters find themselves frequently handicapped in their investigations by the lack of accurate apparatus and instruments, and in order that we may assist amateur readers who experience this difficulty we have undertaken the equipment of an experimental station and laboratory. The laboratory is at present situated in London, but as soon as the necessary arrangements have been made it will be transferred to a country site, free from screening and local interference. Plans have also been made for the erection of a test station, and as soon as our negotiations for a suitable site have been completed we shall announce further details of this part of our service programme. For the moment it is the laboratory which will be of immediate interest to all readers. We are now prepared to give what we may best term " A Calibration Service," whereby any reader may send for calibration any instrument or piece of apparatus. On receipt of the apparatus it will be immediately passed on to our laboratory, where it will be tested against accurate standards without any obligation on the part of the reader other than payment of the sum necessary to cover the cost of return postage. Should readers avail themselves of this offer in numbers beyond all expectations i may be found necessary to make some nominal charge to meet the additional expenditure involved, but for the time being the service is free. There would seem to be no limit to the nature of the calibrations and determinations which we may be asked to make for our readers, but amongst those of primary importance which we are now prepared to undertake are the following :—The measurement of resistance, inductance, and capacity ; the determination of insulation resistance ; transformer constants, and valve constants ; and the calibration of variable capacities, variable inductances, wavemeters, and direct- and alternating-current meters to sensitivities of milli- or micro-volts or amps., according to the nature of the instruments. We refer those of our readers who are interested in this service to the fuller details given on page vi of this issue, but may add that the service will be available from October 8th onwards.

The Price of Components.

The summer slump in the sales of apparatus was attended by marked reductions in prices, not only of complete receivers, but also of components. There is little doubt, however, that the prices demanded by certain dealers for some components are still too high, but while we should like to see reductions in these instances, we would warn our readers against the purchase of exceedingly cheap components, without examining them thoroughly as to their electrical and mechanical capabilities. As an instance of this we may mention some apparatus which we recently examined. A so-called grid leak had an almost infinite resistance, while two variable condensers were finally thrown aside as useless after many hours had been spent in re-assembly. In endeavouring to meet the demands of the public by the production of a really cheap article the manufacturer will find that, unless he maintains a useful standard of quality, he is really doing his trade more harm than good. Unsatisfactory products not only damage the reputation of the individual maker or dealer, but they are hurtful to the industry as a whole by reason of the dissatisfaction and disappointment they produce in the ranks of wireless workers. What the experimenter needs is apparatus which is both electrically and mechanically efficient, and usually he has little interest in other details. The experimenter will pay a fair price if he is sure of getting an efficient article, for efficiency means cheapness in the long run.

The Maintenance of High Frequency Oscillations by Valves.

By E. W. B. GILL, M.A., B.Sc., *Fellow of Merton College, Oxford.*

Most experimenters are, no doubt, familiar with the methods employed in the production of extra high frequency oscillations corresponding to wave-lengths of the order of several metres Wave-lengths of the order of 50cms. can be produced with an ordinary R type valve by virtue of a new principle which has recently been developed, and the general outline of the mode of operation will be found below.

IF an oscillatory circuit consisting of an inductance and capacity be connected to a valve, in which currents are passing, by joining the condenser terminals to two of the electrodes of the valve and if an oscillation is by some means or other set up in the circuit one of two things may happen. Either the alternating potential of the oscillation does work on the electrons moving across the valve. in which case the effect of the valve is to abstract energy from the oscillations and damp them, or the electrons by virtue of their motion do work against the alternating potential, in which case the tendency of the valve is to put energy into the oscillating circuit and sustain the oscillations.

The latter alternative is the underlying principle of the modern methods of maintaining continuous wave oscillations by the use of three-electrode gas-free valves.

As an example, in the ordinary valve generator the oscillatory circuit is connected between the filament and the plate, a battery or other source of high potential being inserted in the plate lead, while a reaction coil is placed between the filament and the grid. This coil is inductively coupled with the inductance of the oscillatory circuit.

If no oscillations are occurring a current i passes through the valve from the filament to the plate, this current consisting of electrons emitted from the hot filament. The size of the current, the filament temperature being kept constant, depends on the voltage V_G between the grid and filament, and also on the voltage V between the plate and filament.

For suitable values of V the plate current is little affected by small variations in V, but is chiefly determined by the value of V_G, the change in the plate current being directly proportional to the change in V_G over a fair range. If, now, a small oscillation is started in the oscillatory circuit (whose resistance will be regarded as very small), the voltage across the condenser may be taken as $V_O \sin pt$ (where V_O is a constant, t represents time, and $2\pi/p$ is the periodic time of the oscillation), and the potential difference between the filament and the plate becomes $V+V_O \sin pt$.

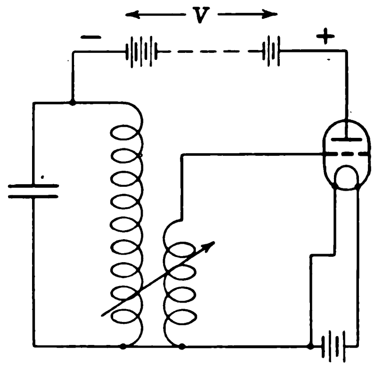


Fig. 1.—In the ordinary valve generator, the oscillatory circuit is connected between the plate and the filament, the plate being maintained at a positive potential.

The effect of the oscillating current in the main circuit inductance is to induce an alternating E.M.F. in the reaction coil, that is, between the filament and grid, which E.M.F. will be practically 180° out of phase with and proportional to the E.M.F. across the condenser if the reaction coil is properly placed with regard to the main inductance.

The net result is that the plate current, which varies linearly with the grid voltage, also varies linearly with $-V_O \sin pt$, and at time t will be equal to $i - k V_O \sin pt$, k being a constant.

At time t an element of charge $(i - k V_O$

$\sin pt)\,dt$ reaches the plate under the voltage $V+V_0 \sin pt$.

The work thus done per cycle on the electrons in the valve as they move from filament to plate is:

$$\int_0^{2\pi/p} (V+V_0 \sin pt)\,(i - k\,V_0 \sin pt)\,dt$$

$$\text{which} = \frac{2\pi}{p}Vi - \frac{\pi}{p}kV_0^2.$$

The second term is the work done by the alternating E.M.F., and as this work is negative, it means that work is got from the electrons which goes to maintain the oscillations.

This can also be seen in another way. The current running through the main battery at time t is $i - k\,V_0 \sin pt$, and the work done per cycle by the battery is therefore

$$\int_0^{2\pi/p} V\,(i - k\,V_0 \sin pt)\,dt$$

which reduces to $\frac{2\pi}{p}Vi$, but the work absorbed by the valve is seen above to be less than this by the amount $\frac{\pi}{p}kV_0^2$, and this amount represents, therefore, a balance of work from the main battery which goes to maintain the oscillation.

The physical explanation is easy to see. If no oscillations occur all the work done by the main battery on the electrons is expended in the valve and appears in the heating of the plate by electronic bombardment. When oscillations occur, the electrons on the average hit the plate with a lower velocity and the heating of the plate is less. The main battery does the same work per unit time in the two cases, and thus part of the work wasted in heating in the first case is used to sustain oscillations in the second. The electrons take energy from the high-tension battery and give out a portion to the oscillatory circuit.

2.—In the above calculation it has been tacitly assumed that the time the electrons take to cross the valve is negligible in comparison with the time of oscillation. The variation of grid voltage operates on the electrons between the filament and the grid, causing a variation in the number which ultimately reach the plate; in assuming, therefore, as was done, that the plate current follows the grid voltage instantaneously the time of passage must be neglected. If, on the other hand, the time of passage is an appreciable fraction of the time of oscillation, the element of charge $(i - k\,V_0 \sin pt)\,dt$ does not move across the valve under an E.M.F. of $V+V_0 \sin pt$, but under an E.M.F. which varies from $V+V_0 \sin pt$ to $V+V_0 \sin p\,(t+T)$, T being the time of passage.

It is of importance to note that in such a case the work done on the electrons cannot be deduced solely from the potential of the plate at the time when the charge reaches it, and that to go through the argument of paragraph 1, putting in a phase angle to allow for the lag of current behind plate voltage on arrival would be incorrect, though the actual effect is similar to what would be produced by such a lag.

Independently of the question of the time that the electrons take to cross the valve, it is doubtful how far the current is controlled by the grid if the oscillations are very rapid. Without, however, trying to apply exact calculation to the case where the time of oscillation is comparable to the time taken by the electrons to cross the valve, it is fairly evident that as the wave-length of the oscillatory circuit is reduced, the valve becomes less and less efficient as a generator owing to the "lag-equivalent" effect.

With ordinary sized transmitting valves, using the ordinary voltages, the time factor begins to become of importance when the wave-length is of the order of 10 to 20 metres. If the valve is of the size of the usual French type, it is difficult to sustain oscillations of much less than two metres.

So far as the time factor is concerned, the production of still shorter waves by the usual methods might be attained by a decrease in the radial dimensions of the valve and an increase in the plate voltages, as each of these changes would make the electrons cross the valves faster; but no very considerable diminution in wave-length can be expected as the fundamental wave-length of the circuit consisting only of the leads inside the valve and the valve capacity, without any external circuits at all, is of the order, for a French valve, of about one metre.

3.—An entirely novel method of producing short waves was announced by Barkhausen

and Kurz in the *Physikalischer Zeitschrift* of January, 1920, by which wave-lengths of from 50 cms. upwards can readily be obtained, though the oscillations are not very strong. In their arrangement the grid of a gas-free valve is charged to a high positive potential V above the filament, and the plate is put at about the same potential as the filament. The oscillatory circuit consisted of two long equal straight wires. If these wires are placed near and parallel to each other they form a so-called Lecher wire system, which has a distributed inductance and capacity. These wires are joined to the plate and grid, and are thus loaded with a small capacity at the end.

This system can oscillate on a fundamental wave-length or on harmonics, which are shorter waves.

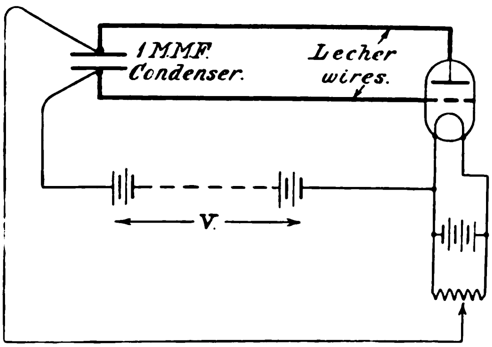


Fig. 2.—The oscillatory circuit comprises a Lecher wire system connected between the grid and the filament, the grid being held at a high positive potential, while the plate is made slightly negative.

It is outside the scope of this article to give in detail the actual experimental arrangements, and we shall concern ourselves merely to indicate that such a system will maintain very short wave oscillations.

The electrons which leave the filament are accelerated up to the grid, and those which pass through are retarded from the grid to the plate. It is only necessary to apply the elementary principles of electrostatics to see that the electrons will just fail to reach the plate, if it is very slightly negative in potential to the filament (provided there are no oscillations); for the electrons having negative charges cannot move from a body of higher potential to one at a lower.

All the velocity they attain under the accelerating force from filament to grid will be lost under the retarding force after passing the grid when they reach a place where the potential is the same as that of the filament, that is, a point just before the plate. The electrons, therefore, turn back near the plate and return to the grid either directly or after one or two more passages backwards and forwards through the grid. It will simplify things to assume the grid spaces are very small compared to the area of the grid wires, in which case the electrons return direct to the grid and do not pass through it a second time.

Thus all the electrons which leave the filament ultimately reach the grid after moving through a potential V and hit it with the same velocity. The work done by the high-tension battery being all devoted to heating the grid by bombardment, the plate receiving no current.

If, however, there is a very small oscillation in the circuit attached to grid and plate the state of affairs is different.

Instead of the old arrangement of potentials

Potential of Filament	O say
Potential of Grid	V
Potential of Plate	O

they become at time t

Filament O

Grid $V - \frac{V_0}{2} \sin pt$

Plate $V + \frac{V_0}{2} \sin pt$

the alternating potential between grid and plate being $V_0 \sin pt$.

It is very easy to see the effect of this if the electron's time of passage is negligible compared to the time of an oscillation.

In the first place, the average grid potential V being high, the current from the filament to the grid can be taken as the saturation current and is unaffected by small alterations in the grid voltage. Grid control, in other words, does not operate, and a uniform current i flows through the grid towards the plate.

In the second place, the plate now receives current intermittently, for when $\frac{V_0}{2} \sin pt$ is positive the plate potential is higher than that of the filament and the electrons, therefore, reach it, while when $\frac{V_0}{2} \sin pt$ is negative the electrons stop just before reaching the plate and return to the grid. Thus plate and grid receive current alternately.

Considering a complete oscillation from $t=o$ to $t=2\pi/p$, from $t=o$ to $t=\pi/p$, the current i passing the grid goes direct to the plate, and from time $t=\pi/p$ to $t=2\pi/p$ the current i goes back to the grid. This would be repeated in succeeding oscillations. In addition there is a current i_1 going direct from the grid to the filament all the time.

The question of whether this arrangement of currents will damp or sustain the oscillations can be answered from the chief principle enunciated that it depends on whether the oscillating potential does work on the electrons or whether the electrons do work against the oscillating potentials.

The work done per cycle by the alternating potential can be divided into three parts:

(A) On the current i_1 going direct from filament to grid the work is

$$\int_{o}^{\frac{2\pi}{p}} -i_1 \frac{V_0}{2} \sin pt \, dt \qquad \text{which is zero.}$$

(B) On the current carried by the electrons which go through the grid, as they go from filament to plate (whether collected on the plate or not), the work is

$$\int_{o}^{\frac{2\pi}{p}} \frac{i\,V_0}{2} \sin pt \, dt \qquad \text{which is also zero.}$$

(C) On the current which returns from just outside the plate to the grid during the time $t=\pi/p$ to $t=2\pi/p$ the work is

$$\int_{\frac{\pi}{p}}^{\frac{2\pi}{p}} -\,i\,V_0 \sin pt \, dt \text{ which is equal to } \frac{2\,i\,V_0}{p}$$

Hence the total work done per cycle by the oscillating potential is $\frac{2\,i\,V_0}{p}$ and as this is positive the electrons gain energy at the expense of the oscillating system, and the oscillations are damped out and not sustained. Thus this arrangement will not act as a valve generator for long waves.

But if the time the electrons take to go across the valve becomes comparable to the time of oscillation things may be very different.

The electron which passes the grid at time t when the plate potential is $\frac{1}{2}V_0 \sin pt$ does not reach the plate till a time T, say, later, when the plate potential has become $\frac{1}{2}V_0 \sin p\,(t+T)$. The electron has, therefore, moved under a potential varying between these limits.

There are two main consequences of this:

1.—The electrons which pass through the grid from time $t=o$ to $t=\pi/p$ no longer all reach the plate. The new criterion for reaching the plate is not whether the plate is positive to the filament when the electron starts, but whether the work done by the varying field on the electron during its passage to the plate is positive. The electrons still run alternately to the plate and back to the grid for time intervals π/p, but these intervals are, so to speak, out of phase with the oscillation, the amount of which they are out of phase depending on the ratio of the time of passage to the time of oscillation.

The net effect of this is to change the limits of the integral in (C) above, and it is clear that if the form of (C) were still correct an appropriate change in the limits would make the value of the integral negative and change the damping of the valve into a regenerative action.

But the form of (C) is no longer quite correct, owing to the second consequence.

2.—That in calculating the work done on an electron, allowance must be made for the variation of potential during its motion.

The full calculations are rather lengthy and tedious, and can be found in the *Philosophical Magazine* for July, 1922, in an article by J. H. Morrell and the author. It will suffice here to give a few calculated numerical results for cases where the work done by the oscillating potential is negative—that is, where the valve maintains the oscillation.

If the ratio of the time of oscillation to the time the electron takes to go from the grid to the plate is 4, then the work done by the oscillating potential is $-\cdot47$ in certain units

If the	ratio is	3	the work is		$-\cdot85$
,,	,,	2	,,		$-\cdot36$
,,	,,	unity	,,		$-\cdot32$

For values of the ratio larger than about 8, the work is positive, and oscillations cannot be maintained.

The result is interesting as showing that the work will reach its largest negative value and regeneration will, therefore, be strongest

for a particular ratio somewhere about 3 of the time of oscillation to time of passage.

The time of passage can fairly easily be seen to be inversely proportional to the square root of V, and hence there is a species of tuning between the voltage used and the wave-length.

This last explains why this method will give shorter waves than the natural wave-length of the valve, and its connections (which limits the wave-length obtained with the ordinary circuit), for if the voltage appropriate to the wave-length of one of the harmonics is applied the set will oscillate on this in preference to oscillating on the fundamental. With ordinary circuits the tendency is for the set always to oscillate on the fundamental.

To give an idea of the sort of wave-length obtained, a French valve with about 200 volts on the grid gives strongest oscillations on a wave-length of about 60 cms. The wave-length is inversely proportional to the square root of the voltage, so that 50 volts would give 120 cms., 800 volts (if the grid would stand it) would give 30 cms., and so on. Valves with larger distances from grid to plate would give longer wave-lengths.

The Fading of Signals.

By O. F. BROWN, M.A., B.Sc.
(*Technical Secretary to the Radio Research Board.*)

The effects of fading of short wave signals are too apparent to the experimenter to need discussion, while on the other hand little is known of the cause. The Radio Research Board is at the present time conducting an investigation, and have asked for the co-operation of the amateur. In the following pages the factors determining the received signal strength are considered.

FROM the earliest days of radio-telegraphy it has been known that radio signals may vary in strength quite apart from faults or lack of adjustment of the apparatus at the transmitting or receiving station. An operator may be listening to good signals from a distant station when these may gradually decrease in strength, until sometimes they become too weak to read, and then increase again until they become stronger than they were originally. Such phenomena are described as "fading effects," and their explanation is to be sought in the factors influencing the propagation of the wireless waves in the intervening space between the transmitter and receiver.

Fading effects are more commonly met with in the reception of short waves (*i.e.*, waves of the order of 600 metres and below) received by night over long distances. The increase in the numbers receiving broadcast signals, and also the increase in amateur communication over long ranges (as, for example, the reception of American amateur stations in this country), have brought these effects recently into great prominence.

The growing interest in short wave communication is to be welcomed by all interested in the scientific aspects of wireless communication, because the study of transmission on such waves is likely to lead to the collection of valuable data bearing on the solution of problems of the propagation of waves, the explanation of which are at present matters of conjecture.

Fading effects are closely allied to other phenomena of wireless transmission, such as the fact that the range of a wireless station using short waves is always greater by night than by day, or the occurrence of freak ranges when signals from a station usually inaudible at a particular spot can be heard occasionally by night. Any general hypothesis advanced to explain any one of these effects must be capable of explaining the others.

The hypothesis which is generally accepted to-day is that the upper rarefied regions of the atmosphere contain a large quantity of

minute dust particles charged with electricity which have been driven out from the sun and caught in our atmosphere. Such particles have the effect of making the portions of the atmosphere in which they occur semi-conductors of electricity. The physical constitution of the upper atmosphere makes it probable that these particles are sorted into more or less definite layers, the lowest of which may be supposed to be about 100 kilometres from the surface of the earth. At night time these layers, encircling the earth as a semi-conducting shell, may be expected to have fairly sharply defined under surfaces. Under the direct influence of sunlight, however, it is probable that the rarefied gases of the atmosphere are directly ionised; that is, the atoms which compose them are broken up into positive and negative particles called ions. These ions will penetrate into the atmosphere to distances considerably below the permanent semi-conducting layers already described.

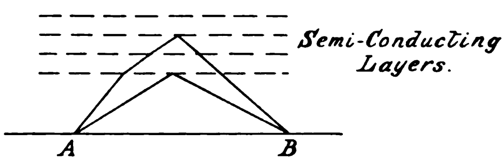


Fig. 1.—By night, waves from the point A, reach B, by the path shown.

After sunset, when the direct action of the sun is removed, the positive and negative ions recombine, leaving the space below the lowest permanent semi-conducting layer practically free from ions, and therefore an insulator.

Several years ago a classic series of experiments carried out by Austin and Cohen led to a somewhat complicated empirical formula being evolved giving the strength of the voltage to be expected at a receiving aerial at various distances from the transmitter. Recently Prof. G. N. Watson has shown mathematically that, assuming wireless waves are conducted round the earth in an insulating shell between a semi-conducting earth and a semi-conducting layer in the atmosphere, a formula exactly of the same form as the Austin-Cohen formula is obtained, and this result lends very strong mathematical support to the supposed existence of such layers in the atmosphere.

We may now consider the effect of the ionisation on the propagation of wireless waves. When a medium is a semi-conductor the effect is to increase the velocity with which a wave passing through the medium travels. In the daytime, therefore, when the under surface of the lowest semi-conducting layer is ill-defined, the upper portions of a wave from a transmitting station will pass through an ionised portion of the atmosphere. These portions of the wave will travel faster than the lower portions which travel along the earth's surface, and the wave will therefore be tilted over or refracted towards the earth and will be absorbed in the ground. Also, when the waves are passing over dry soil, which is not a good conductor of electricity, the foot of the waves will be pulled backwards, so that absorption by the ground will take place more quickly than if the wave were passing over sea water, for example. There is in addition probably an absorption and scattering of the actual energy of the wave by the charged particles in the medium, and this absorption is greater for short waves than for long waves. The general effect of these factors is to make the day range of short waves comparatively small.

At night the lower portions of the atmosphere are clear of ions and the surface of the semi-conductive layers more sharply defined. Thus, instead of the waves entering a charged medium and being refracted, they will encounter charged layers which can act as semi-reflecting surfaces, just as the surface of water acts as a partial reflector for light waves. As the short waves are more easily absorbed so, from the physical principles involved, they may be expected to be more easily reflected than longer waves. The layers are semi-transparent to the waves, and part of the energy in the waves will be transmitted and refracted by each layer and part will be reflected. The amount of energy reflected depends on the angle at which the waves meet the surface. If this is a large angle most of the energy will pass through the layer; as the angle gets smaller more energy is reflected.

By night, then, waves from a point A may be supposed to reach B by paths such as are shown in Fig. 1. Although the layers at night are moderately well defined, it is to be expected that the shape of the layers is continually varying, and the paths by

which waves may reach B from A will be affected by the changes in the surfaces of the layers. The signals received, therefore, will be by no means constant in strength; in other words, "fading" effects will certainly occur at night either through changes in the constitution of the semi-reflecting surface or through changes in the direction of the layers, both of which factors will affect the paths taken by the waves. Figs. 2 and 3 illustrate roughly how the variation in signal strength may arise through alterations in the arrangement of

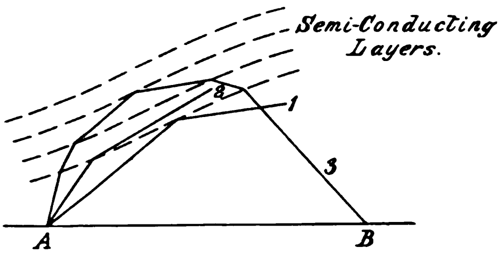


Fig. 2.—If the layers become bent, waves travelling along paths (1) and (2) are reflected and refracted and are lost by absorption in the upper atmosphere, while those travelling more vertically reach B by the path (3).

the layers. Should the layers be bent as shown in Fig. 2, then waves travelling along paths (1) and (2) are reflected and refracted so as to be lost and absorbed in the upper atmosphere. The waves following path (3) which reach B are those radiated in a more vertical direction than those reaching B in Fig. 1. As very little energy is usually radiated vertically from an ordinary aerial the signal strength at B will be decreased. Similarly from Fig. 3 it is seen that if the layers lie in the other direction the strength of signals at B will be increased.

It thus appears that the strength of signals received especially on short waves, will be influenced by the condition, as regards conductivity, of the portions of the atmosphere through which the waves pass. The paths which the waves take will depend on the sharpness of the ionised layers, and the number of charged particles in the layers from moment to moment, and even on the varying arrangement of the particles in the layers.

The strength of the signals may also depend on the nature of the ground between the receiver and the transmitter, and may be influenced by changes in its electrical conductivity produced by the presence or absence of rain. The signals may, in addition, vary through the changes in the electrical state of the lower atmosphere. For example, the presence of thunder clouds may cause local absorption or deflection of the waves.

In particular, just at sunset and sunrise the changes taking place in the conductivity of the atmosphere will be very great, as the direct ionising effects of the sun will cease and begin at those times. Fading effects may, therefore, be expected to be very pronounced, and experience fully supports this expectation.

The only way in which these complicated phenomena can be investigated is by carefully organised simultaneous observations carried out over a long period. The Radio Research Board established under the Department of Scientific and Industrial Research has taken a step towards the investigation of the problem along these lines by enlisting the co-operation of amateurs through the Radio Society of Great Britain and its affiliated societies. In many districts arrangements have been made for several observers to record the strength of the signals from the Broadcasting Stations, whose transmissions are on wave-lengths likely

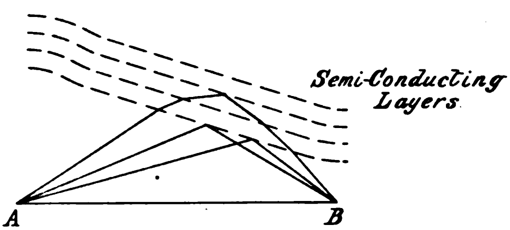


Fig. 3.—Here, the layers lie in the opposite direction, thus causing the signals to be increased in the direction of B.

to show fading effects, and to forward their observations monthly to the Secretary of the Board for analysis. The measurement of signal strength, unfortunately, is a matter of the greatest difficulty if accurate results are desired, and it is impossible outside a fully-equipped laboratory. Isolated observations may, therefore, not always be reliable. Nevertheless, if the variation of signals are observed simultaneously by several independent observers reliable qualitative data at least are likely to be collected, which will be of great value in the elucidation of the problems of wireless transmission.—*Published by permission of the Radio Research Board.*

Neon Lamps and Their Use for Wireless Purposes.

By E. H. ROBINSON.

Gas discharge devices have occupied the attention of the experimenters for some considerable time, the Geissler tube, for example, being many years old. The neon tube is very convenient for experimental work in that it requires an ionising potential of only a few hundred volts. The recent appearance of the neon tube as a commercial article for the purpose of illumination is most opportune as it provides the experimenter with a suitable discharge device at a reasonable price. Below will be found much information relating to the use of neon lamps for reception, transmission and other purposes.

NEON lamps have been attracting the attention of experimenters for some time past, and it seems that they may in the near future find several useful applications both in wireless transmission and reception. Perhaps it would be more correct to say that already they have, in the hands of a few amateurs who have taken the trouble to experiment with them, proved successful for certain purposes which formerly could only be served by the much more costly thermionic valve. The following remarks may help to give the reader an idea of the properties of neon lamps and the sort of thing they may be expected to do.

The "Osglim."

At the time of writing the most familiar type of neon lamp on the market is the "Osglim," made by the G.E.C. These lamps are similar to the old Geissler tubes, in that a luminous ionised-gas discharge takes place between metallic electrodes in a rarified atmosphere, with the difference that the ordinary Geissler tube requires a potential of several thousand volts across its terminals as against only about 200 volts in the case of the neon lamp. This difference is chiefly due to the abnormally low ionising potential of neon gas, and its high electrical conductivity when ionised. The electrodes of the "Osglim" lamp, which, by the way, are made of iron, are much closer together than in the older type of "vacuum tube." The space within these lamps contains nearly pure neon* under a pressure corresponding to several millimetres, or even a centimetre or two, of mercury. Thus, judging by modern standards, the vacuum is an extremely "soft" one. The neon usually contains a small percentage of helium, and sometimes a trace of hydrogen may be added by the makers, as this tends to prevent disintegration of the electrodes. The writer believes that a little mercury vapour is also present. Certain impurities, however, such as water vapour, must be religiously excluded during manufacture as they are detrimental to the proper action of the lamp.

Before experimenting with a commercially made neon lamp it is advisable to remove the safety resistance which lies hidden in the brass cap of the lamp, as it may seriously modify the action of the lamp, especially where H.F. currents are involved. The most obvious way of removing the resistance is to cut round the brass cap with a small pair of scissors so that part can be removed, allowing one to get the resistance out and to take leads direct from the electrodes. It is, however, much more convenient to preserve the cap intact so that the lamp can be inserted in standard bayonet holders for subsequent experiments. This can be done by the following procedure. The lamp is held by the bulb, as shown in Fig. 1, and the brass cap is carefully heated by a small bunsen flame applied to the end where the contacts are, special care being taken that the flame does not play on the glass. This heating has the double effect of melting the solder which secures the lead-in wires to the contact lugs, and of softening the cement which holds the bulb in the cap, so that the cap can be readily removed by grasping with a pair of tongs or pliers and pulling gently. The cap thus removed reveals the resistance which usually takes the form of a quantity of fine insulated wire wound on

* One of the five completely inert gases that are present in small quantities in our atmosphere.

a piece of cardboard or an earthenware bobbin. The removal of the resistance now presents no difficulty, and the brass cap may be fixed on again with elastic glue or similar cement after suitable connection has been established between the lead-in wires and the contact lugs.

When the safety resistance has been removed it is not safe to put a neon lamp straight across the lighting mains, as excessive pulses of current are likely to run through it and blow the fuses. When working off the mains some external limiting device, such as a lamp, should be used in series.

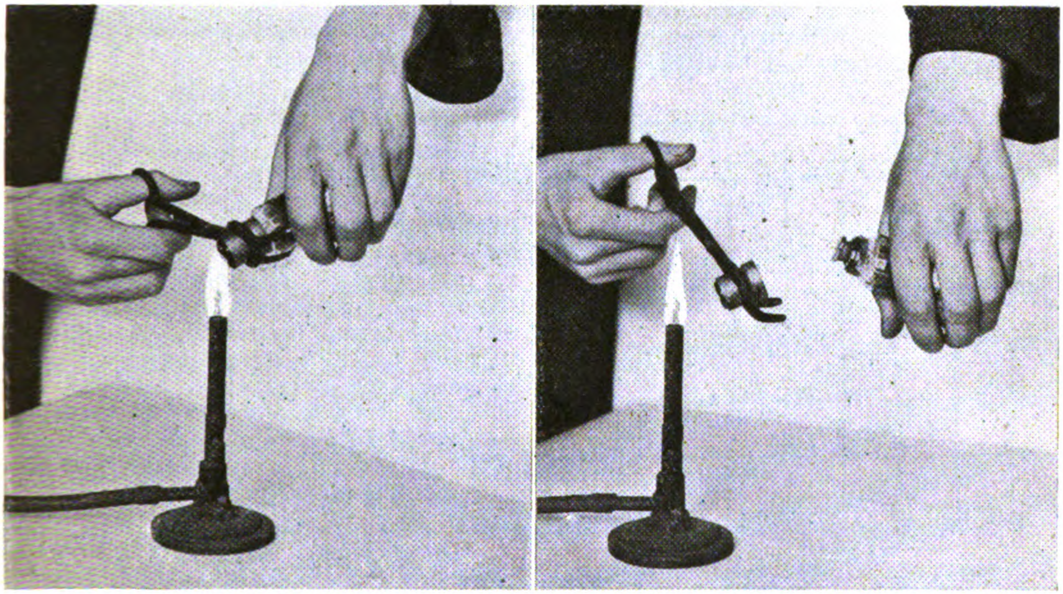


Fig. 1.—On the left the Osglim is held with a pair of tongs, and a small flame is applied to the end of the cap until the solder securing the leads melts, when the cap can be pulled away, as seen on the right, exposing the resistance.

Characteristics of the Neon Tube.

Most of the interesting properties of the neon lamp depend on the fact that as a conductor of electricity it does not obey Ohm's law. Fig. 2 is the characteristic curve of a typical lamp. Hardly any two lamps appear to have exactly the same characteristics, and the curves of some neon lamps show abrupt kinks where the discharge suddenly spreads to another part of the electrodes or alters its whole distribution. Such kinks are particularly common in lamps having irregularly-shaped cathodes, such as the star type or certain of the letter-lamps. The lighting-up and extinction voltages of a neon lamp are not the same; that is to say, there is a certain minimum potential below which the discharge will not start, but once the discharge has been started by applying this potential (or a higher one) the glow may be maintained by a potential appreciably below that required for starting. In this respect the neon lamp resembles an arc lamp, though the effect is more pronounced in an arc lamp. Another property of neon lamps is that if the electrodes are of unequal size the conductivity is not the same both ways, the lamp conducting best when the largest electrode is the cathode. It will be born in mind that in the "Osglim" lamps the glow appears at the cathode, which is the fancy electrode, and which has a much greater surface area than the anode. Thus, if the lamp is put in its socket the wrong way round, the glow appears at the smaller electrode and less current will be found to pass through the lamp than when it is connected in the normal way. A certain lamp of the "Beehive" type when tested in this way on a voltage of about 200, passed 15 milliamperes in the normal direction and 13 in the reverse direction. In many lamps,

however, this uni-directional effect is much more marked. Not only is the conductivity of neon lamps different when they are connected with different polarities, but the minimum ignition potentials are different, a lamp lighting up on a lower voltage when the smaller electrode is made the cathode.

It might be as well to mention here that neon lamps should not be run on voltages much in excess of the rated value if it is desired that they should retain their original properties. If a 220-volt lamp is run for about a quarter of an hour on four or five hundred volts it glows with abnormal brilliancy and heats up considerably, the electrodes, especially the smaller one, becoming read hot and the bulb becoming too hot

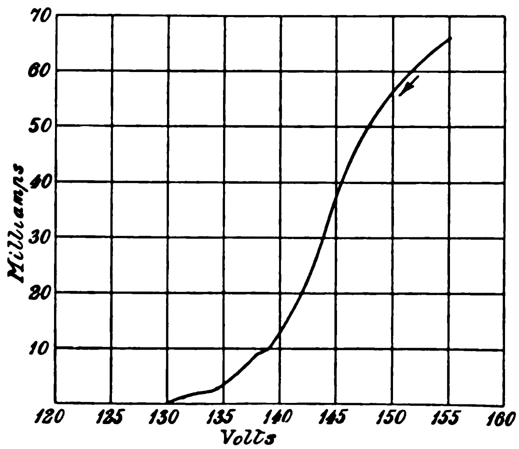


Fig. 2.—Showing the general form of the characteristic curve of a Dutch double spiral neon tube, as taken by the author. The arrow indicates that it is an extinction curve.

to touch. After a few minutes of this treatment the glow changes from the original pinkish-orange colour to a pale lilac fringed with blue or green. Once a lamp has been over-run to this extent it requires a higher voltage than the rated value to work it afterwards, and it will always light up the pale lilac colour. Over-running spoils a lamp for many purposes, but the writer finds that the oscillatory properties referred to below are often improved to a great extent.

Rectification.

Owing to the partial uni-lateral conductivity a certain amount of rectification can be obtained with a neon lamp, although the rectification obtained is very incomplete and probably will not in itself find a very extended application. Fig. 3 shows how a neon lamp may be used as a detector to receive sufficiently loud signals. The neon lamp V is connected across the A.T.I. in series with a pair of 'phones, a high variable resistance R and a 200-volt H.T. supply. C is a large bye-pass condenser, which is not absolutely essential. By means of R the potential across the lamp is adjusted until the lamp glows feebly. This arrangement, using an "Osglim" lamp, is rather insensitive and is inferior to a good crystal detector, very little being audible in it other than a local broadcasting station. Nevertheless, the writer can receive 2LO very clearly if not very loudly, in this manner. It might be of use, however, for a separate "side-tone" receiver for those who experiment with the transmission of radio-telephony. A difficulty that one usually meets in trying to listen to one's own transmission is that most detectors, including valves, tend to be paralysed by the powerful local oscillations of the transmitter. A neon lamp used as a detector is practically free from paralytic effects.

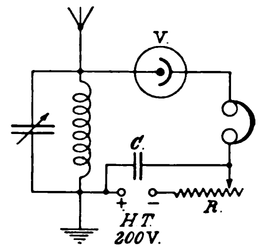


Fig. 3.—Method of using the neon tube as a detector.

Production of Oscillations.

One of the most interesting properties of neon lamps is their capability of converting a direct-current supply into regularly pulsating current. If a lamp is shunted, as in Fig. 4, by a variable condenser C fed through a resistance R from a D.C. supply of 200 volts or more a rapid series of pulses will pass through the lamp when R is increased until the lamp is just on the point of extinction. This is due to the arc-like property of the lamp previously referred to. The number of discharges per second through the lamp depends upon the rate at which the supply current through the resistance R can charge the condenser C up to the ignition potential of the lamp. Thus by decreasing R the frequency of the pulses is increased, and also the smaller C is made the higher will be the discharge frequency. By suitable

adjustments of R and C the frequency may be made such that the lamp only flashes once every few seconds, or it may be made of any desired musical pitch. It is necessary to have the potential drop in R about equal to that in the lamp—that is to say, R must be of the same order of resistance as the lamp. A simple water resistance is convenient for experimental purposes. With

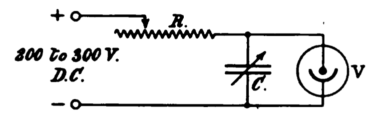


Fig. 4.—The neon lamp is shunted by a condenser supplied through a high resistance, the frequency being determined by the values of R and C.

most neon lamps the frequency can be carried just above the limit of audibility, but it is not usually possible to carry the pulsations much further into the radio frequencies, the average lamp ceasing to function at about 25,000 per second, after which the glow is continuous and not interrupted. Owing to the fact that these pulsations are detached uni-directional surges, as shown in Fig. 5, and are not sinusoidal oscillations, an enormous number of harmonics are present. If we make a neon lamp pulsate in the manner described above at a frequency of about 15,000 and listen in a heterodyne receiver close to the lamp we hear a strong C.W. note due to the fundamental pulsations on a long wavelength of 20,000 metres or so, and as we tune the receiver down to shorter wavelengths we come to harmonics of two, three, four, five, and so on, times the fundamental frequency, and it follows that the higher the frequency we tune to the more crowded together these harmonics will be. This is, indeed, no case of "the higher you go the fewer." On the shorter wavelengths below 400 metres the harmonics become extremely feeble, but follow each other in rapid succession as the tuning condenser of the heterodyne receiver is varied.

The harmonics of a neon lamp, far from being a disadvantage, make it possible to generate low power C.W. on short wavelengths in spite of the fact that the lamp itself will only pulsate on frequencies corresponding to very long wavelengths. By tuning an oscillatory circuit associated with the neon lamp circuit to one of the short-wave harmonics, this harmonic is made to stand out very much more strongly than the rest, and will produce loud heterodyne effects in an adjacent receiver. The writer has found the connections shown in Fig. 6 best for this purpose. Suppose that it is desired to produce oscillations of a frequency of 1,000,000 (corresponding to a wavelength of 300 metres) in the circuit L2C2 (Fig. 6). The neon lamp V is connected up to produce pulsations, as in Fig. 4, except that an inductance L1 is included in series with the lamp. R and C1 are adjusted to make the lamp pulsate at as high a frequency as possible; the higher this fundamental frequency can be made the stronger and purer will be the C.W. produced at the desired

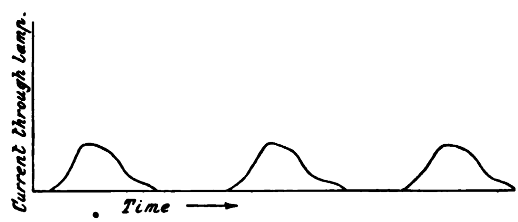


Fig. 5.—The wave form of pulses produced by a neon lamp, showing their non-sinusoidal nature.

harmonic frequency. C1 may be a .001 mf. variable condenser at about half-way setting. The inductance L1 must be of such a value that in conjunction with C1 it would tune approximately to the same frequency as L2C2—that is to say, 1 000,000 per second in this case. The circuit C1 L1V is not a tuned circuit in the ordinary sense of the word, owing to the inclusion of the lamp V, but the adjustment referred to ensures a maximum transference of energy on the harmonic frequency from the lamp circuit to the tuned circuit L2C2. Once the circuit L2C2 has been tuned to the desired frequency a slight adjustment of C1 or R will serve to bring a harmonic into exact synchronisation with L2C2, in which case the C.W. produced is at its strongest and purest. The coupling between L1 and L2 requires a certain amount of adjustment, and should be made quite tight. H.F. chokes may be put in the supply leads, as shown in Fig. 6, but they are not always necessary as the resistance R is usually very high, and is sufficient in itself to keep H.F. currents out of the supply leads. If the arrangement is used for low power

transmission the closed circuit L2C2 is replaced by a tuned aerial circuit. The whole action of the arrangement is that of impact excitation, each aperiodic discharge pulse through the lamp giving a kick to the circuit L2C2, which continues to oscillate in its own free period until the next pulse comes to keep it going. The process of tuning L2C2 to a harmonic simply amounts to making the lamp circuit give the circuit L2C2 a kick at intervals of an exact number of oscillations. Thus, if the lamp is discharging at 20,000 per second and L2C2 is tuned to a frequency of 1,000,000, the circuit L2C2 receives a kick exactly every 50 oscillations, and if this circuit is one with low H.F. losses practically undamped oscillations are sustained in it. The principle is exactly the same as that used in the Chaffee, Ditcham, and T.Y.K. systems of producing C.W., with the difference that these systems used a highly-quenched spark-gap in place of the neon lamp, and were capable of dealing with powers of 100 watts or more.

The Neon Tube as an Oscillator.

The first difficulty that one encounters when one tries to use the neon lamp oscillator for transmission is the minuteness of the power obtainable. Although the standard "Osglims" are intended to consume 5 watts normally, most of them will only pulsate when they are on the point of extinction and consuming considerably less than 1 watt. Many lamps are capable of great improvement in this respect by over-running on about 400 volts until the glow changes to a pale lilac colour. This not only makes it possible for the lamp to pulsate subsequently on greater power, but enables it to pulsate on a somewhat higher fundamental frequency and to give much more powerful harmonics.

When a neon lamp is being used, as in Fig. 6, to produce continuous oscillations it is highly important to have the supply current absolutely constant. It will be born in mind that the fundamental frequency is not determined as in a valve transmitter by a tuned circuit, but is chiefly a function of the supply current and the condenser in the neon lamp circuit. Thus small variations in the supply current cause corresponding variations in the fundamental pulsation frequency of the lamp which are enormously exaggerated in the harmonic selected by the circuit L2C2 (Fig. 6). For example, the writer was making a neon lamp oscillator give C.W. on 400 metres, rectified A.C. being used as the source of current. Although the smoothing arrangements were such that absolutely pure C.W. would have been given on a 10-watt valve transmitter, the oscillations from the neon lamp sounded in a heterodyne receiver as if entirely unsmoothed A.C. were being used. It was not until a smoothing system consisting of two intervalve transformers and condensers amounting to 10 mf. was used that pure C.W. was obtained, and this in spite of the fact that only about 5 milliamperes were being drawn from the H.T. supply. When once the supply has been made sufficiently smooth the C.W. note is as pure as that obtained from a valve transmitter.

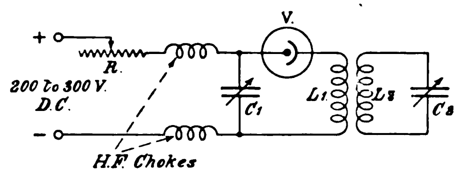


Fig. 6.—Here a harmonic from a pulsating neon lamp is selected by a tuned circuit L 2C2.

The susceptibility of the oscillations to variations in the supply current has one advantage, in that very sensitive telephonic modulation can be obtained by simply inserting the secondary of a modulation transformer in series with the H.T. supply.

The Effect of other Gases.

So far reference has been made only to the use of neon lamps as oscillators, but the writer has found that the properties referred to above are by no means confined to vacuum tubes employing neon gas. Neon lamps are convenient simply because of the low voltages required to work them, and because they are readily obtainable at a moderate price. Other gases and vapours give similar and even greatly improved results. A simple air vacuum will work after a fashion, while ammonia gas is quite good. Very good results are obtainable from lamps containing a mixture of phosphorus and mercury vapour. In one set of experiments the pip of an "Osglim" was removed so as to let the air in, and to let the neon escape. A glass exhausting tube was now sealed on to the bulb, and a drop of mercury, along with a

few grains of red phosphorus, was introduced; connection was made by rubber pressure tubing to an ordinary filter pump working on a water tap at full mains pressure. This pump was capable of exhausting to a pressure corresponding to about 1 cm. of mercury. During exhaustion a potential of 500 volts A.C. was applied to the electrodes, this causing a bluish-violet glow to take place between them, and making them red-hot. At the same time the lamp was shaken so that some of the red phosphorus fell on to the hot electrodes, and became converted into yellow phosphorus, which vaporised and combined with any residual oxygen in the bulb. The exhaustion was continued for about five minutes, and the exhaustion tube was sealed off near the bulb with the lamp still glowing. Several lamps were prepared in this way, and though they did not all behave in exactly the same manner, they were nearly all much better oscillators than the ordinary neon lamp. One tube in particular gave very good results, as it would pulsate on a power of over three watts at a fundamental frequency as high as 50,000 (*i.e.*, 6,000 metres wave-length). The writer has not been able to obtain such a high frequency with a neon lamp. The tube in question was rather difficult to start up, and required about 400 volts to work it, but it was capable of putting ·1 amp. into an average aerial on 440 metres, the arrangement in Fig. 6 being used with the aerial circuit in place of the closed circuit L_2C_2. The C.W. heterodyne note was as pure as that from a valve transmitter. These phosphorus vapour lamps might very well be developed into a practical article for regular use, and they can be constructed at a negligible cost by anyone with a little experience of glass working. Much better results could probably be obtained by using specially designed electrodes made of some more suitable metal than iron.

Early Discharge Devices.

The idea of using a discharge in a partial vacuum to produce C.W. is by no means new, and was brought to the stage of practical utility in 1916 by Japanese radio engineers in the form of the T.Y.K. vacuum discharger. The T.Y.K. discharger consisted of two circular parallel electrodes sealed into a glass bulb evacuated to a pressure of a centimetre or two of mercury. The anode was of copper, the cathode of aluminium, and the distance between the electrodes was about half a millimetre. The discharger really amounts to a Chaffee gap in a partial vacuum. The atmosphere in the discharger may be air, but ammonia gas was found to give greatly superior results. The T.Y.K. discharger dissipated about 100 watts, and was fed from a 500-volt supply, the circuit used being almost identical with Fig. 6.

The whole subject of using neon lamps and similar devices is an interesting and extensive one, and we hope to be able to publish further accounts of it in future issues of this journal.

It is possible to use a neon lamp as a modulating device in a radio-telephone transmitter. The writer does not at present claim that a neon lamp gives better results

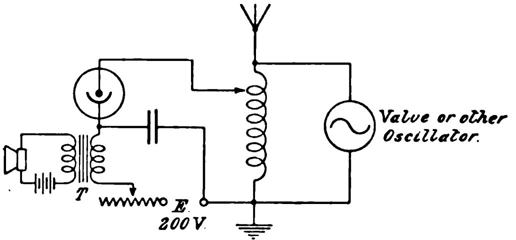


Fig. 7.—The lamp is shunted in series with the modulation transformer across the A.T.I. of the transmitter. A source of polarising potential should preferably be included in series with the lamp.

as a modulator than as an ordinary thermionic valve, but it is a very inexpensive substitute, has no filament, and is certainly capable of giving quite good results. The simplest modulation scheme using a neon lamp is shown in Fig. 7; it amounts to the converse of the receiver in Fig. 3. Shunted across the aerial circuit is the lamp in series with the secondary of a step-up modulation transformer T, and a source E of polarising potential. By means of a resistance R the potential across the lamp is adjusted until it glows feebly; a certain amount of glow is also caused by the H.F. potentials, derived from the aerial inductance. When the microphone is spoken into, the potentials set up across the secondary of the transformer T vary the conductivity of the lamp (owing to its non-linear characteristic), causing a varying damping effect on the aerial circuit. This system of modulation can be applied to a 5-watt valve transmitter with satis-

factory results, but the writer prefers the arrangement shown in Fig. 8. Here the ordinary electrodes of the lamp do not constitute an absorption path in themselves, but a third electrode is made by placing an insulated metallic coating round the outside of the bulb. This may consist of tinfoil neatly stuck on to the glass with shellac varnish or other adhesive. The tinfoil should cover nearly the whole of the bulb, but on no account should it touch the brass cap or any other conductor at earth potential. A piece of copper wire is bound round the bulb so as to make good contact with the tinfoil, and connection is made thereby to the grid of the transmitter valve. One of the leads to the internal electrodes of the lamp is connected to the filament lead, the two internal electrodes being connected in series with the secondary of a step-up modulation transformer, and a source of variable polarising potential. When the lamp glows its interior becomes semi-conductive, and its capacity effect with the tinfoil outside forms quite a good conducting path for H.F. currents. The arrangement may be used as a shunt control across either the grid circuit or the plate circuit of the valve transmitter. Most effective modulation can be obtained by using a tuned grid circuit and shunting the absorption modulator across this. Similar circuits, using valve modulators, are quite well known to most experimenters. By

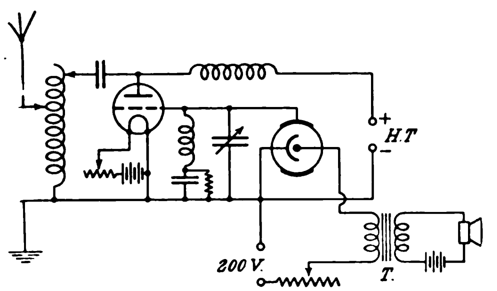


Fig. 8.—The internal electrodes are connected across the secondary of the modulation transformer, the auxiliary electrode being taken to the grid of the transmitting valve.

adjustment of the tuning condenser across the grid circuit one can obtain a flexible control of the extent of modulation. In either of the systems shown in Figs. 7 and 8, the polarising potential for the neon lamp may be derived from the same H.T. source as is used to supply the oscillator, a suitable resistance being inserted in series with the lamp if necessary, to cut down the voltage across the lamp to the right value. In the figures a separate H.T. supply is shown for simplicity.

Other Uses of the Neon Lamp.

Other uses for neon lamps have suggested themselves, and have been put successfully into practice. Fig. 10 shows how a neon lamp may be used to obtain rectified high-tension

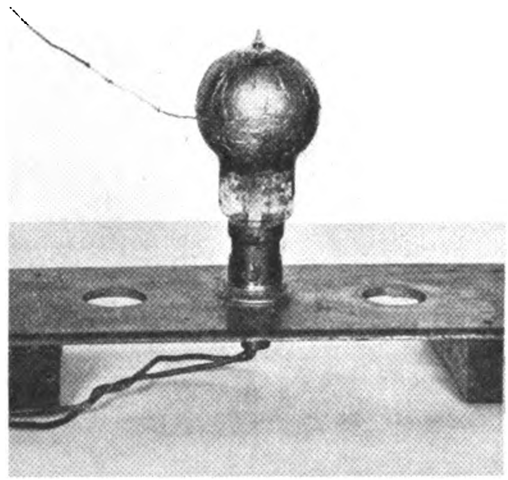


Fig. 9.—Tinfoil is fixed to the glass with shellac to form the third electrode.

currents from a spark coil suitable for C.W. and telephony valve transmitters; PS is an induction coil, preferably of the type with a high speed interrupter and capable of giving comparatively heavy currents in the secondary at a voltage of a thousand or so. The neon lamp V is placed in series with secondary S as shown, C1 and C2 being smoothing condensers whose necessary value will be determined chiefly by the interruption frequency in the primary P. These condensers, especially C1, should be built to withstand fairly high peak voltages. The fact that a rectified output is obtained from the condenser C2 does not depend so much upon the unilateral properties of the lamp itself as upon the peculiar wave-form of the secondary voltage of an induction coil. When the interrupter in the primary "makes" the circuit, only a low voltage of certain polarity is set up across the secondary, and this is

insufficient to drive any current through the lamp. On "break," however, a very high potential surge of opposite polarity is set up in the secondary, and this passes through the lamp easily, and charges the condensers C1 and C2. Since only the break surges get through the lamp, and since these are always of the same polarity, it follows that the condensers will charge up, and D.C.

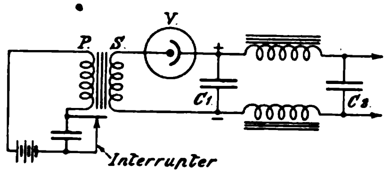
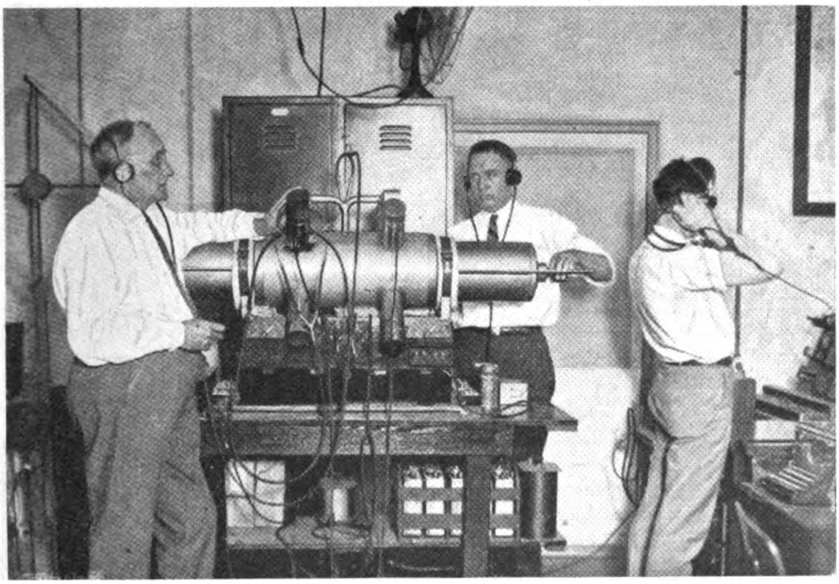


Fig. 10.—A neon lamp in series with the secondary of the induction coil allows only pulses due to the break to pass into the output.

can be drawn from them. Only one lamp is shown in Fig. 10, but it will usually be necessary to use two or three neon lamps in series, as one will not stand a back voltage greater than about 200. This method of using neon lamps is particularly applicable to H.T. units of the well-known "T.V.T." type.

An example of the useful application of neon lamps to wireless reception is to be found in the Anson Relay. As this device has already been described in the technical press, it will not be dealt with at length here. The broad principle consists in placing a neon lamp in the plate circuit of a three-electrode valve and adjusting the H.T. supply so that the lamp works near its extinction point. The input-output characteristic can be steepened in this way so that the current through the plate circuit when no signal is arriving is negligible compared with the current that is set up when a signal does arrive. This enables a relay in the plate circuit to work cleanly and precisely. Also the extra resistance due to the neon lamp reduces the time constant of the relay circuit and allows a higher working speed.

A variety of miscellaneous uses will, no doubt, occur to the experimenter. Long-wave oscillations produced directly by a neon lamp may be used for heterodyne reception of stations like Carnarvon. Also a lamp pulsating near the limit of audibility might be applied to the Armstrong super-regenerative receiver. The object of this article will have been accomplished if it has helped to give an idea of the possibilities in neon lamps and to stimulate some of the readers of this journal to make further experiments for themselves in this direction.



The above photograph, of American origin, shows another attempt at static elimination. Being dissatisfied with radio and audio frequency eliminators, attention has been turned to acoustic methods, and the photograph should form excellent subject-matter for amateur experiments in this direction.

Antenna Constants.

By H. ANDREWES, B.Sc., A.C.G.I., D.I.C.

It is impossible to bring a transmitter to a state of efficiency without a knowledge of the aerial constants, particularly the effective resistance. The following article explains how the radiation resistance may be measured, and is, perhaps, the best method for the experimenter, as it involves little calculation and practically no additional apparatus.

THE aerial, or, more correctly, the antenna system, of an amateur transmitter is very often a much neglected-portion of the station, not so much, perhaps, from the point of view of putting up a large, high elaborate aerial, but owing to the fact that the actual efficiency of the system as a radiator is not known. Without careful measurement it is impossible even to estimate the radiating efficiency, and only a poor idea of the efficiency of the oscillator can be obtained from the anode current and the aerial current. It is not, perhaps, generally realised that the measurement of the "so-called" constants of an antenna is not really such a difficult problem, and that most of the apparatus is available to the average transmitting licence-holder.

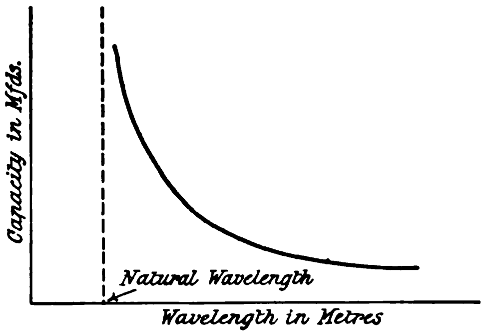


Fig. 1.—The capacity of an aerial varies with the wave-length, and the general form of the curve showing the relation can be seen from the above figure.

Now, every aerial system has inductance, capacity and resistance, and hence a natural wave-length at which it will oscillate when unloaded. With small antennas, such as are usually used, at any rate, for 200-metre work, the inductance is usually neglected, as it is fairly small. This, of course, introduces an approximation, and hence we must remember this if the capacity is to be measured by substitution.

The two most important properties of the antenna are the capacity and the resistance. By resistance is meant the effective resistance. Later it will be shown how this may be split up into its three components.

The first thing we must do is to measure the natural wave-length of the system. Then, knowing this, we may measure the capacity and resistance above this for a series of wave-lengths and hence obtain curves showing us the variation of these "constants."

Variation of Capacity with Wave-length.

It is not, perhaps, always realised that the capacity of the antenna varies with the wave-length, and hence it is only true to say that a certain antenna has a capacity of, shall we say, ·0005 mfd. for a certain fixed wave-length. The general shape of the capacity-wave-length curve is shown in Fig. 1.

The easiest way to describe how to make these measurements will be to describe, briefly, the apparatus and method used to obtain resistance and capacity curves at the author's station.

The general method is to obtain a small current in the antenna at a given wave-length, and then switch the oscillator on to an artificial aerial consisting of capacity and resistance, and adjusting the capacity for resonance and the resistance to give the same current. Then, approximately, the capacity and resistance of the antenna are given by the values in the artificial circuit for the given wave-length. To prevent reactions between the artificial and oscillating circuits, and to keep the conditions the same for aerial and artificial circuits, it is essential to use extremely loose coupling between the oscillator or "driver," as it is often called, and the A.T.I. For this reason it is usual to set up the driver about 10 ft. away from the lead-in and A.T.I. and

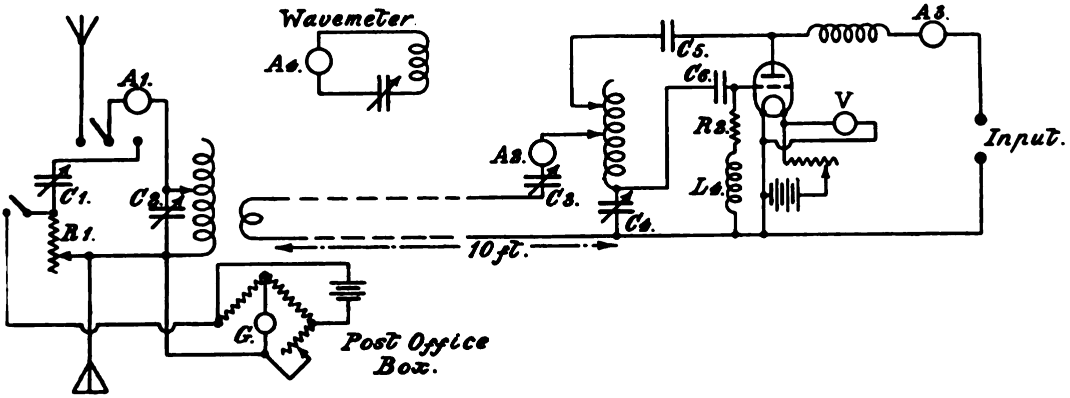


Fig. 2.—The oscillator on the right produces a small current in the aerial circuit, which is then substituted by the artificial circuit adjusted to give the same aerial current. The oscillator, or driver, must be at least 10 ft. from the artificial circuit in order to prevent capacity and reaction effects.

then run long straight wires or flex from the driver to a coupling coil coupled to the A.T.I.

The Driver.

For the driver any ordinary oscillatory circuit may be used. In the general circuit diagram (Fig. 2) the Colpitts is shown. One essential point about the driver is that it should be of sufficient power. In the case in question a French 60-watt tube was used, with 1,200 volts "raw" A.C. on the anode. Owing to the nature of the oscillatory circuit employed a "phantom" circuit was placed where normally the aerial circuit would be connected and the coupling coil to the A.T.I. included in this circuit. This was found to be advantageous, as up to 5 amps. could be obtained in this circuit, allowing loose coupling to the aerial, and at the same time it was possible to change the wave-length by altering the "phantom" circuit condenser without shutting down the circuit, as changing the clips necessitated.

The following are details of the apparatus shown in Fig. 2:—

A_1 = aerial hot-wire milliammeter.
A_2 = "phantom" circuit hot-wire ammeter, 0—7 amps.
A_3 = anode input ammeter, 0—150 D.C. milliamperes.
A_4 = wavemeter hot-wire milliammeter, 0—250.
C_1 = 1 jar Navy variable.
C_2 = ·0005 mfd. variable.
C_3 = ·001 mfd. variable; high insulation.
C_4 = ·001 mfd. variable; high insulation.
C_5 = anode stopping, ·01 fixed.
C_6 = grid, ·01 fixed.
L_1 = ordinary helix to be used on transmitter.
L_2 = three-turn coupling coil (about 1 ft. diam.).
L_3 = "driver" helix (bare wire, good insulation).
L_4 = grid H.F. choke (any fairly large inductance).
L_5 = anode feed H.F. choke (any fairly large inductance).
R_1 = Artificial aerial resistance. A straight Eureka wire with sliding clip.
R_2 = water grid leak, variable.

In order to take a reading the procedure was as follows:—The driver was started and the wave-length adjusted to a suitable value by means of C_3 and C_4, and as large a current as possible obtained in A_2. The wave-length was then accurately measured

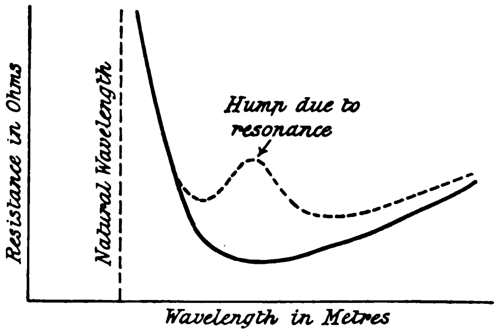


Fig. 3.—The variation of resistance with wave-length can be easily seen from the above curve. The peculiar shape is brought about by resonance with some near conductor.

by means of the wavemeter. The change-over switch was then placed on the aerial side and the aerial circuit brought into resonance with L_1 and C_2, and the coupling between L_1 and L_2 adjusted to give from 50—100 milliamperes in A_1.

With a fairly large value, for safety, in R_1 the switch was thrown over and the

artificial circuit brought into resonance by means of C_1 and the current in A_1 brought to the previous value by altering R_1. The value of R_1 is then obtained from the P.O. box.

It is advisable to test at the beginning for reaction by moving the change-over switch backwards and forwards and noting if there was any change in A_2 or A_3 readings.

A Low-Loss Condenser.

The following important points should be noted. The condenser C_1 in the artificial circuit must be a good low-loss one. This is absolutely essential, as the author has found by experience. At first an ordinary receiving condenser was used immersed in paraffin to increase the capacity. This gave a resistance for the antenna at a certain point of about 5 ohms ; on replacing this by a good condenser the value of R rose to 20 ohms. This may have been due largely to the paraffin, but still indicates the necessity for a good condenser.

The coupling between L_1 and L_2 should not be too loose, as otherwise it was found that the artificial circuit was difficult to manage and absurd results were obtained. By using a P.O. box to measure the value of R any errors due to loose contact, etc., to the resistance wire were avoided, but, of course, by careful construction, this could be avoided, and the P.O. box is not an essential. The condenser C_2 need not be a low-loss one, as its resistance does not enter into the measurements.

With the above apparatus, and with careful measurements, it will be seen that curves may be drawn from the readings obtained of the capacity and effective resistance of the aerial system with varying wave-length. Fig. 3 shows the theoretical shape of such curves. As a rule, the capacity curve follows in practice the theoretical shape, but very often the resistance curve has serious humps in it. These are usually due to resonance in some object near the aerial, such as another aerial, telephone wires, etc. These can only be remedied by the removal of the object, a possible cause of friction if your neighbour is a "broadcast listener-in"! If by luck you get a curve such as Fig. 3 it is then possible to split up the effective resistance into its components. There are three losses in the aerial system which appear as resistance in their curve, namely: (*a*) Radiation resistance; (*b*) dielectric losses; (*c*) ohmic resistance. These may be represented as shown in Fig. 4. The radiation resistance is a curve as shown. The dielectric losses increase with the wave-length, while the ohmic losses remain constant.

It can be seen, then, that by geometry the various components may be determined.

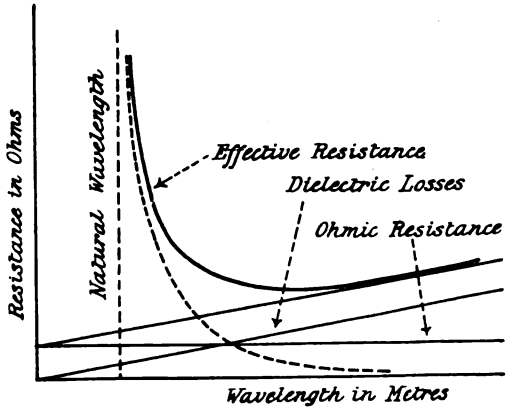


Fig. 4.—The components of the effective resistance of the aerial are clearly demonstrated by the above curves.

The important point is that, in this way, we may find the efficiency of the antenna system at different wave-lengths, *i.e.*, watts radiated to watts in the aerial, and it is easy to see that the point of maximum aerial current is not necessarily the best working point. It should be noted that if an oscillating circuit such as the Colpitts be used for the transmitter the curves obtained do not hold as a series aerial condenser is introduced. This may be obviously remedied by taking the curve with the condenser in circuit at various settings.

Trans-Atlantic Signals Coming Over Again.

Experimenters report the reception of quite a number of American amateur stations during the last few weeks. Broadcasting stations can also be heard on wave-lengths from 300 and 400 metres between the hours of 00.30 and 3.30 G.M.T. Although the carrier-waves of several of these stations are usually fairly easy to detect, and the modulation is readable at times on a good receiver, the strength of the signals is not yet up to what may be expected at the most favourable times during the winter.

Some Notes on Distortionless Amplification.

The following article shows where distortion is likely to occur in power amplifiers, and gives interesting data for the production of pure speech and music from loud speakers.

IT is a regrettable fact that, perhaps, not more than five per cent. of the broadcast receivers fitted with loud speakers give results approximating to clear speech and music. A recent examination of a number of installations, both amateur receivers and demonstration models, showed that the results were absolutely deplorable, the speech, in some case, being absolutely unintelligible. Such a condition must necessarily have a very malign effect upon broadcasting, and in the interests of wireless it is surely the duty of the experimenter to demonstrate that the faithful reproduction of speech is no mere hypothesis, but is, on the other hand, an assured fact. It is the object of these short notes to indicate the most usual causes of distortion, and explain how the original quality of the speech may be retained by the correct adjustment of the apparatus.

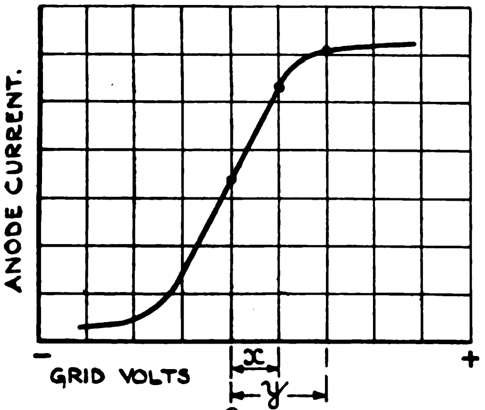


Fig. 1.—When the potentials reach a value of "y" distortion occurs.

The idea seems to be prevalent that the distortion is invariably due to bad design of the low-frequency transformers and the loud speaker. In the majority of cases nothing could be more erroneous, the trouble usually being associated with conditions under which the valves are functioning. In order to examine all the possible causes of distortion the whole system will be examined progressively, dealing with each individual component very briefly. It will be assumed that the carrier wave is modulated as perfectly as possible, and it may, therefore, be considered as distortionless. The quality of a modulated wave is dependent upon the percentage modulation, which, in the case of a broadcast station, is considerably smaller than that used by the average amateur experimenter, resulting in better quality of speech.

Crystal Rectification.

The first component of the receiving apparatus is the tuning system, and calls for no attention. Following this is the rectifier, unless radio-frequency amplification is employed, which will be considered later. It will be seen that if any distortion takes place here its effect will be greatly magnified by the subsequent low-frequency amplifiers, and consequently it is of vital importance to obtain distortionless rectification. Most receivers employ cumulative grid condenser rectification, which functions by virtue of the change in grid current. This method is undoubtedly the most efficient, but is likely to produce more distortion of the original wave form than other systems. The value of the grid leak is a very critical factor, and is determined by the constants of the circuit. It is essential, therefore, that it should be found by trial. The writer is in favour of connecting it between the grid and the positive side of the filament battery. It will probably be found that the value of the leak which gives the clearest speech does not give the greatest volume of sound. It is, no doubt, advisable to sacrifice strength at the expense of quality, thereby giving a somewhat lower efficiency per valve.

Crystal rectification is a far simpler problem, and there is little to choose between a good crystal and a valve rectifier without reaction. The crystal rectifies owing to the asymmetrical nature of the contact resistance, and it can be shown that less distortion is likely to be produced than with a valve. The next part of the receiver is the low-

frequency amplifier, and is responsible for a good proportion of the bad quality of the speech.

Linear Amplification.

The magnitude of the potentials applied to the first amplifier will be dependent upon the strength of the rectified oscillations, which, in the case of broadcasting, will be fairly large. In order to obtain proper amplification the change in anode current must be directly proportional to the applied potentials, which in this case are fairly large. This means that the portion of the curve over which the valve is being used must be represented by a straight line. This condition can be fulfilled by arranging the steady grid potential so that the operating point is brought to the middle of the straight part of the curve. This adjustment alone is not sufficient. It will be seen by referring to Fig. 1 that as long as the applied potentials do not exceed a value of "*x*" linear amplification occurs, but when they reach a value of "*y*" the operative point moves to the upper bend of the characteristic. The obvious remedy is to lengthen the curve, which simply necessitates increasing the filament emission, by brightening the filament or substituting a valve having a greater emissivity. This may produce saturation at the particular anode voltage. In order to restore normal working conditions it will be necessary to increase the voltage on the anode to some extent.

It will be seen, then, that the filament must be fairly bright, and that a large voltage should be used on the anode. For an ordinary R-type valve about 80 to 100 volts should be used on the first amplifier. The voltage on the anode has an effect upon the normal working point on the curve. Increasing the voltage has the effect of moving the whole curve to the left, which thus determines the correct steady grid potential. From Fig. 2 it will be seen that when the anode voltage is 50 the grid potential should be about zero. When the voltage is increased to 100 the necessary grid potential would be about 3 volts. It has been shown that, owing to the magnitude of the applied potentials, it is necessary to use a long curve, which further necessitates a steady negative potential on the grid. In practice this is best obtained by the introduction of grid cells, and will be referred to later. There is an additional advantage obtained by the use of the negative potential, since, if of sufficient magnitude, the strongest positive potential applied by the incoming signal can never give the grid an absolute positive potential. This means that no grid current will flow which would produce distortion.

Increased Power in each Stage.

The above reasoning holds good in the case of the next stage of amplification, only in this case the applied potentials are considerably greater. Thus, if the first amplifier is working at the maximum

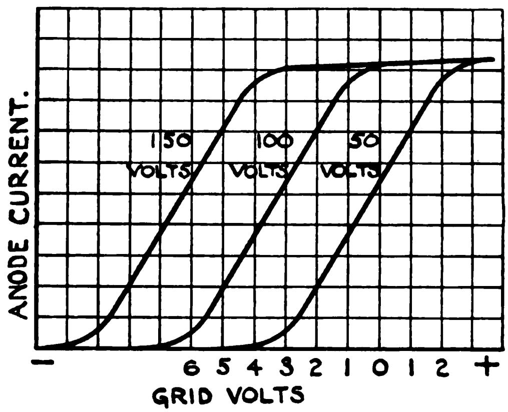


Fig. 2.—As the anode voltage is increased, the curve moves to the left.

efficiency it follows that the available power in the next stage must be increased. This means that a greater anode voltage must be used, and a greater negative grid bias will also be required. Similarly a third stage will require even greater values. It is impossible to give absolute values without the various constants of the circuit, but they should be determined as follows. The first stage of amplification should be connected, making the filament fairly bright, and using about 70 volts on the anode. If signals are at all strong a loud speaker must be used in place of telephones, as it is impossible to judge the quality with an over-loaded telephone. It is advisable also to use a crystal as the rectifier. The grid bias should then be adjusted in conjunction with the anode voltage. As the grid is made negative the strength and quality of the signal will

improve, and will continue to do so until a critical value at which maximum amplification will be obtained. When this point is reached it is advisable to see if increasing the anode voltage will give a further increase in signal strength. The same procedure is then carried out with the subsequent stages. As a rough guide, the following table shows the comparative values of the voltages required for successive stages of amplification :—

Valve.	Grid Bias.	Anode Voltage.	Valve.
1st Stage	— 2	100	R type.
2nd Stage	— 6	150	Very hard R type.
3rd Stage	—12	300	Small power valve

Another cause of distortion is sometimes due to excessive radio-frequency amplification. Too many stages of radio-frequency amplification build up such big potentials that they are not only distorted in the last

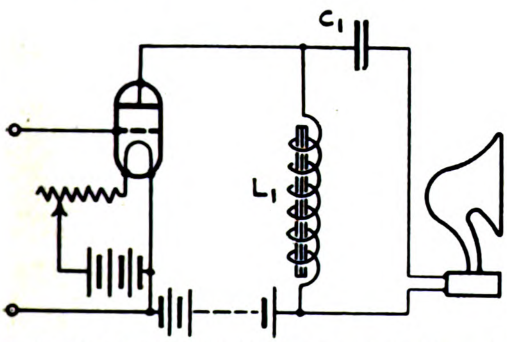


Fig. 3.—The loud speaker is connected across a choke L_T through a condenser C_1.

stage of radio-frequency amplification, but are not properly rectified, the peak voltages being lost which are responsible for the quality of the speech. The resulting speech is "tinny" and "rustly." The remedy is obvious, it being merely necessary to cut out the unnecessary stages of amplification.

Loud Speaker Connections.

With regard to the loud speaker, it must be remembered that it is by means of this that the quality of the speech is judged, and it must be assumed that there is nothing wrong with it. If another type is available it is useful to make all tests with each of the loud speakers. It will probably be found that a small condenser of about 0·002 mfd. in shunt will improve the quality to some extent. An arrangement sometimes employed with very satisfactory results is shown in Fig. 3. It will be seen that the loud speaker is connected across a large choke of the order of 2 Henries through a condenser of about 1 mfd.

If bad speech and music are still obtained the trouble probably lies in the instruments, or more often in their arrangement. A tendency to howl and a muffled sound is generally due to low-frequency reaction, which should always be avoided. Adjustment of the filaments will usually remedy this, or it may be necessary to try a different arrangement of the transformers. Many transformers have a large magnetic leakage, and interaction between the fields giving rise to a form of trouble which is best remedied by screening or alternatively the substitution of another transformer. A number of transformers have a ratio as large as 1 to 5, and are rather liable to give trouble by oscillating at an audible frequency, especially when there is a large negative grid bias. This can sometimes be rectified by experimenting with small condensers connected across the primary windings and elsewhere. The writer is in favour of ratios not greater than about 1 to 3·5, but it should be remembered that a transformer should really be made to suit the circuit and not the circuit to suit the transformer, as is unfortunately the case.

There is one form of distortion which is very hard to eliminate. Speech and music constitute a very large band of audible frequencies, the higher harmonics approaching radio frequencies. It is obviously very hard to arrange two or three transformers and a loud speaker so that they will respond proportionally to applied potentials at all frequencies from several hundreds to several thousands. The transformers are best suited for middle frequencies. The very low frequencies require a very large reactance value for the transformers. If this is provided the secondary reactance must be increased proportionally in order to keep the transformation ratio constant. The additional winding increases the self-capacity of the secondary enormously, with the result that it has a by-passing effect, especially on the

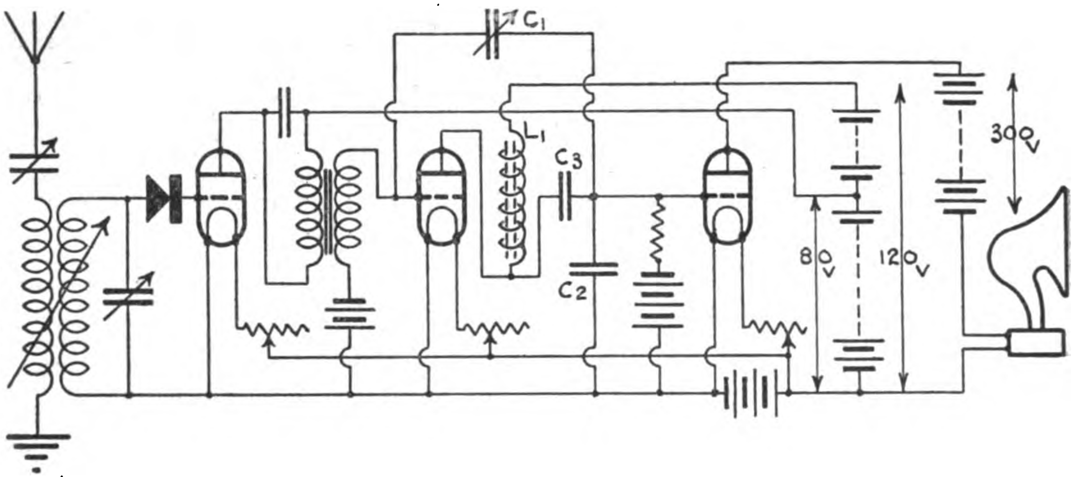


Fig. 4.—A novel circuit embodying several interesting features. The condenser C_1 is used to obtain negative audio frequency reaction and C_2 is used to by-pass high audio frequencies which are amplified too much by the second valve.

higher speech frequencies. It is obvious, then, that if an unequal amplification occurs, more particularly with music, that the original timbre and colour can never be faithfully reproduced. The resistance coupled amplifier, being aperiodic, is more perfect in this respect, but requires very careful adjustment, and, of course, no voltage step up is obtained with successive stages of amplification.

An Interesting Circuit.

Much time and experiment can be devoted to distortionless amplification, and, in conclusion, some details of a circuit which has a moderately high efficiency will, no doubt, be of interest Rectification is obtained by a crystal, which is connected directly to the first valve, the anode voltage being about 80. This is coupled to the next valve by a 1 to 3 transformer, shunted by a condenser of about ·0002 mfd., the anode voltage being about 120. The second valve is coupled to a Marconi Osram T15 by a large choke, the secondary winding of an old motor spark coil being suitable. The coupling condenser is 0·25 mfd., and the grid leak is about one megohm connected to an 8-volt grid cell. Owing to the large emission from the filament the grid normally assumes a large negative potential, and the grid cell can sometimes be dispensed with, depending upon the actual conditions of the circuit. It will be seen that a separate anode supply of the order of 300 volts is used for the last valve. In order to keep the loud speaker at earth potential it is included in the negative lead, the positive going direct to the anode. This particular circuit was found to amplify the higher frequencies too much, and this was overcome to a certain extent by shunting the grid and filament of the last valve with a 0·002 mfd. condenser. If low-frequency reaction is present to any extent a condenser of about 0·0003 mfd. can be placed between the grids of the last two valves. The value, of course, is rather critical. Experimenters who are interested in pure reproduction will find the subject of distortionless amplification very fascinating if they care to approach it by what the writer has termed "constructive amplification," which if not a truly scientific method, is both instructive and interesting. Having rectified the incoming oscillations as purely as possible, they are amplified by several low frequency stages, various devices being included to control the degree of amplification of various bands of frequencies. It will be seen from the foregoing notes that distortion is chiefly due to the working conditions of the instruments and not to the apparatus itself, and consequently any experimenter who is pleased to allow his loud speaker to emit anything but perfectly intelligible speech and music rich in tone and colour is doing little else but demonstrating his unfamiliarity with wireless apparatus, and is at the same time prejudicing his friends against broadcasting.

P. D. T.

Efficient Transmission.

By FREDERIC L. HOGG.

Many experimenters interested in transmission are content to connect an ordinary valve oscillator to a receiving aerial and expect good results. The following article, by an experimenter who has been heard in America, will show that many special circuits and arrangements are necessary for efficient transmission.

THE subject of efficiency in transmission has not had much attention paid to it by radio amateurs in this country. Perhaps this is due to the lack of information about transmission in radio journals, and it is hoped that many will now give their experiences and information to others through this magazine.

The usual procedure in making a transmitter is to build up a nice set in a box, using the conventional reaction circuit—or "reversed feed back"—and to fiddle with this till the ammeter moves a bit. Having got a reading on the ammeter the input is pushed up to an unmentionable value till there is an appreciable aerial current. Most people affirm that it is impossible to have more than, say, ·8 amp. in the aerial on 10 watts, and that ·5 is a good average. This is absolutely incorrect. On any ordinary aerial a current of at least 1 amp. should be obtained, and more under good circumstances.

How many amateurs who have really good receivers have found it possible to build their receivers without a considerable amount of experimental work? Of course, anyone can make a receiver work, but what is meant is the kind of receiver which will give good transatlantic results.

Considering the fact that in a receiver one can allow a considerable amount of loss which will be counteracted by reaction, and that in a transmitter such losses must be made up by input power, it is obvious that far more care must be taken over the transmitter. The usual receiving aerial and earth are generally no use at all for transmission, but when they are made suitable for transmission a difference in reception will be noticed. This is a point very few realise; it is far harder to make a really successful transmitter than it is to make a good receiver. The remarks I propose to make on this subject will refer to 200-metre work in the main, although they will apply to a certain extent to the higher waves as well.

The Aerial System.

First of all, let us take the aerial system. It is well known that a curve can be drawn showing the resistance of the aerial at different wave-lengths. A typical curve is shown in Fig. 1. The total resistance R_a is made up of three separate components, *i.e.*, the true radiation resistance of the aerial (representing the actual energy used usefully) – R_r; the losses due to ground resistance and wire resistance, etc., – R_g; and the dielectric losses due to houses,

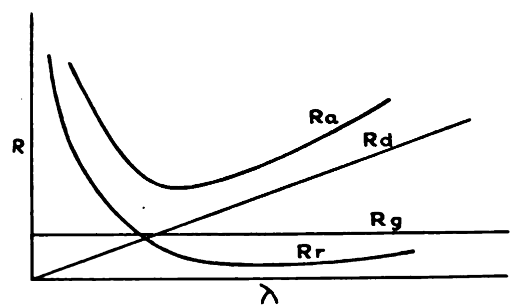


Fig. 1.—Illustrating the three components of the radiation resistance curve of a typical aerial.

trees, etc., – R_d. These three components are shown in the figure. For the moment this will be assumed, but possibly may be discussed at length in a future article. It will be seen that near the fundamental the total R_g and R_d are least and that R_r is greatest. From this it has been assumed that the best point at which to work an aerial is at its fundamental, as here R_r is theoretically infinite. This view is particularly popular in the U.S.A., but, while I agree as regards theory, in practice things appear very different. However, whether the reader agrees or not, he will grant this point: Given any particular wave, the higher the radiation

current on that wave and aerial the more efficient the transmitter.

Before proceeding a note on fundamentals would not be out of place. We all know that the fundamental of an L aerial is approximately $4\frac{1}{4}$ times its length in metres or 1·5 times its length in feet. But this is usually quite wrong when applied to amateur aerials, for not only must we count the length of aerial, but also the lead-in and earth lead. As an example, my own aerial, which is an exaggerated case, will be quoted. Length of top, 60 ft.; length of down lead to roof, 15 ft.; length from lead-in to set, 10 ft.; length from set to level of counterpoise, 45 ft.; total, 130 ft. This gives a natural wave-length of about 195 metres. The actual natural wave-length is 192 metres. Most people would say such an aerial would have a natural wave of about 90—100 metres. I have found by trial on quite a number of aerials that 1·5 times the length in feet of all leads from earth or counterpoise level to free end of aerial gives a very good approximation. Now this explains why people have difficulty in getting down to short waves.

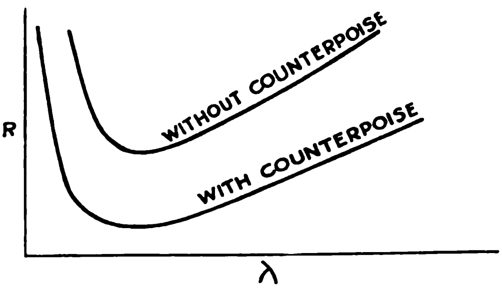


Fig. 2.—It will be seen that the use of a counterpoise lowers the radiation resistance of the aerial to a considerable extent.

We see, then, that we can get greater aerial currents by eliminating the wasteful R_d and R_g losses. R_d is, unfortunately, usually fixed for any particular location, though if the operator can remove all trees, houses, etc., in the neighbourhood so much the better! Often a noticeable difference is made by carefully breaking and insulating all guys, etc., and keeping the aerial well away from the masts. However, in most cases R_g is the factor which counts most. The usual water pipe earth has a colossal resistance, and buried plates have too small an active area to be any use for transmitting.

The Counterpoise.

The only thing to do is to use a counterpoise under the aerial. This should be as large as possible, and perfectly insulated, about 6 ft. above the ground in the ideal case, although in practice a couple of wires 10 or 12 ft. above the ground under the aerial are often far better than the usual earths. Also the capacity and natural wave-length fall, which is, in many cases, an advantage, as a bigger inductance can be used in the aerial circuit, with better transference of energy. This, of course, only applies in some cases. Anyhow, the first thing to do is to put up as large a counterpoise with as many wires as possible. The smaller the amount of the sky visible from the ground the better. The whole must be insulated just as carefully as is the aerial. With quite a small counterpoise of six wires spaced a foot apart, and 12 ft. high, the resistance of my own aerial was reduced from 38 to 5 ohms on 200 metres, which is certainly an extreme case, but I have heard of worse cases. It is safe to say that in every case of an average amateur station a counterpoise will improve results. Having now a counterpoise, we have reduced R_g considerably, which is a considerable advantage. We have also altered our fundamental a little if the counterpoise is small, but this is not of great significance. As to the aerial itself, a larger number of wires than are used for reception are probably an advantage —three or four are generally suitable. A cage has a very slight theoretical advantage in some circumstances, but is not always worth the trouble of building. A well-spaced (4 or 5 ft.) four-wire flat top is as good as anything to begin with. The usual wire is quite suitable, but it should preferably be enamelled. The insulation must be far better than usual. The ordinary small shell or egg insulators are no good unless they are cleaned every few days. They are quite useless for large aerial currents also. If nothing better can be obtained a string of at least three insulators should be placed at each end of each wire. The best insulators to use are 12-in. or 18-in. glazed porcelain rods of best quality. Composition and ebonite insulators should invariably be avoided. The importance of insulation is still greater on high powers, say 100 watts and over; the ordinary types will brush

over and the composition ones melt. The lead-in is of equal importance. A large porcelain tube should be used, or, if possible, no lead-in tube at all.

Aerial Current.

Having now a good aerial, we can proceed to other parts of the set. But first let us consider what aerial currents we should get on 10 watts input. We all know that—

watts input × efficiency = watts output.
And watts = (current)^2 × resistance of circuit.
∴ watts input to anode × efficiency = (aerial current)^2 × R_a.

Now the efficiency and R_a are both unknown, but if we can tabulate $\frac{R_a}{\eta}$, where η is the efficiency, we can get an idea of what is taking place. The smaller this figure the better our transmitter. It is usually assumed that η is ·5 for a valve, but this figure can be easily exceeded. Many commercial stations have efficiencies of ·85 to ·9, and ·75 should be obtained by any amateur. The efficiency is governed largely by the

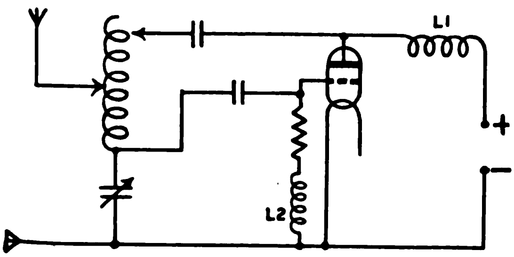


Fig. 3.—Colpitt's Oscillator. Here the grid coupling is capacitative. The choke (L2) in series with the grid leak should always be used when the leak is connected to the filament.

anode tap, grid leak and H.T. voltage. To a certain extent the greater the values of these three the greater the efficiency, though, of course, there are many other factors. Now, at its lowest point the resistance of an average amateur aerial with counterpoise is below 10 ohms. If it is not, there is something wrong somewhere. The number of aerials with a higher resistance is very small indeed, and many fall as low as 5 ohms or less. Now, if we have an input of 10 watts in a 10-ohm aerial at ·75 efficiency we get an aerial current of ·87 amp. With a little care the 10 ohms can be reduced to 5 ohms and the efficiency increased to ·8, which gives us a current of 1·26 amps. These figures show us there is something wrong with the average ·5 or ·6.

If the aerial resistance is above 5 ohms at its lowest point the trouble is probably due to ground resistance and can be reduced, but this subject will be dealt with later. We will consider the subject of efficiency inside rather than outside the station. If we have any sort of an aerial we should be

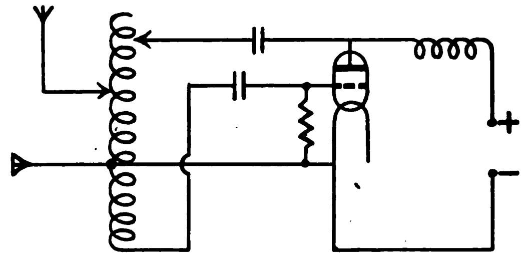


Fig. 4.—The Hartley circuit is somewhat similar to the Colpitts, and is better suited to low impedance valves.

getting somewhere about 1 amp. of aerial current.

An important point to consider is the earth-counterpoise arrangement. To start with, at any rate, it is best to use only a perfectly insulated counterpoise. Later, earths can be added, tuned by condensers. This will prevent certain difficulties arising. If an earth and a counterpoise are connected together to a set the aerial current usually goes down, for the currents in the two will be out of phase because of their different capacities and resistances. Each separate earth must be tuned, which, of course, is a complication, and should only be attempted when results on counterpoise alone are efficient. If an earthed H.T. supply is used an R.F. choke should be placed in series with each lead, which will eliminate the trouble.

The Aerial Ammeter.

The next point to consider is one of the utmost importance, which is usually neglected, *i.e.*, the aerial ammeter. Most people get a hot wire 0—·5 instrument, and try to get it off the scale before proceeding further. But if we have an aerial whose resistance is, say, 10 ohms, and put in an instrument with a resistance of 5 ohms—which is the resistance of such a meter—we are losing a third of our aerial power. The 0—1·5-amp. type has a resistance of 1—1·5 ohms, which is

an enormous difference in practice. As an example, on a certain set with a 0·5 ammeter of 4·58 ohms resistance and a 6-ohm aerial a current of ·45 amp. was obtained. On substituting a 0—1·5 of 1·29 ohms resistance the current was ·82 amp. Here, of course, the efficiency altered, but especially when using a fairly low H.T. voltage a slight decrease of resistance will increase the efficiency when other adjustments fail. I have known of several cases where the whole trouble of seemingly poor

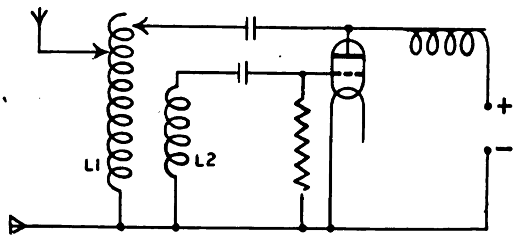


Fig. 5.—The Reversed Feedback or reaction circuit is most familiar, and is suitable for general work.

results was due to the aerial ammeter. An ammeter should always be checked, if possible, against a standard instrument. They will read fairly accurately on D.C., as the inductance is very small. If no standard is available a lot can be done with a 2-volt accumulator and an accurate D.C. voltmeter or ammeter. If an ammeter is obtainable the procedure is obvious. If a voltmeter is used a small known series resistance must be used, and the current can be calculated by the volt drop across the resistance. The inaccuracy can often be corrected to a great extent by altering the tension of the wire and re-setting the pointer, but it should be checked over the whole range if possible. A thermocouple is, of course, better, but is usually out of the question for most amateurs on account of the high price. They can be depended upon for years, while a hot-wire ammeter needs checking every few months.

Transmission Circuits.

Now as to the circuit to use. There are seven main types of circuits to use, *i.e.*, Colpitts, Hartley, Meissner, reversed feed back (direct or loose coupled), master oscillator, and ratio tap. These are illustrated in Figs. 3 to 9. Most of these names are American, I know, but it is much easier to have a name than to describe the circuit each time. Let us consider these one by one.

The Colpitts circuit is the easiest circuit to get satisfactory results from, and gives, as a rule, a greater efficiency than any other circuit. It is ideal for rapid wave-changing, only two adjustments being necessary to cover a band of, say, 100 metres. Also the series condenser enables a larger aerial to be used than is possible on other circuits, as a certain amount of inductance must be in the aerial circuit to get a transfer of energy from valve to aerial. But, you may say, one can use a series condenser on any circuit. This is quite true, but for some obscure reason the Colpitts series condenser and other series condensers have not the same effect. It is possible to use quite a high loss condenser in the Colpitts circuit without effect, whereas this is fatal in any other case. This is not a particular experience, but is the result of tests at a number of stations. There is as yet no explanation forthcoming for such behaviour as this, but the fact remains that in the ordinary case a series condenser is inefficient, whereas on a Colpitts it is anything but. The aerial inductance should be larger than usual, and the series condenser should be about ·001 mfd.

The Hartley circuit does not appear to be very successful in England. In America it is used a great deal for high-power work,

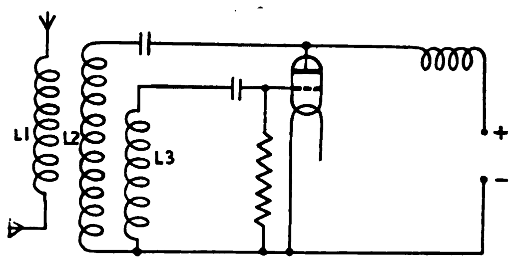


Fig. 6.—Illustrating the loose-coupled reaction circuit. Here again a choke is placed in the anode circuit, which is always necessary when the anode is supplied in shunt.

but it does not appear to suit our valves. The aerial coil again needs to be of very large inductance. This circuit is of more use for artificial circuits, drivers, etc., than for ordinary work. It will not give results on a high-resistance aerial, nor on high impedance valves, which last accounts for its prominence in the States and not here, as American valves are of much lower impedance than ours.

The reversed feed back circuit is our usual two-coil reaction circuit, which nearly everyone uses. This is a very straightforward circuit, and works very well if care is given to the value of anode tap.

The loose-coupled reversed feed back is sometimes used, but has little advantage for amateur work.

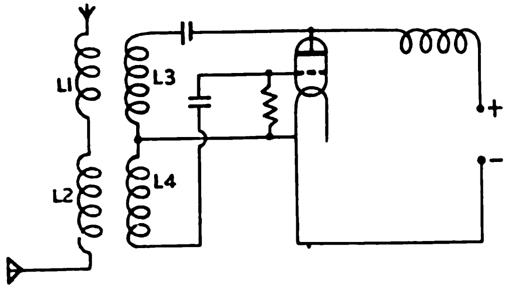


Fig. 7.—In the Meissner oscillator, the aerial inductance is split and the anode and grid coils are each coupled to one half.

The Meissner circuit is really the loose-coupled reversed feed back circuit rearranged. The aerial coil is split into two parts, and the plate and grid coils are each coupled to one part, but not to each other. This is supposed to lead to simple wave-changing, but whether this is so is a matter of opinion.

The master oscillator is really the ideal circuit, but it requires very careful handling, and an extra valve. On high-power work, also, the power valve has to be of larger size than usual in case it should stop oscillating, which is more likely with this circuit than any other. The grid of the power

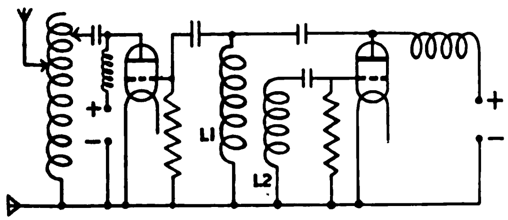


Fig. 8.—The oscillations are produced by L1, L2, and control the grid of the power valve.

valve is connected to an oscillator tuned to the required wave, and so the plate output frequency is independent of the aerial tuning, resulting in a perfectly constant wave-length, however much the aerial may swing. A receiving valve will control a 30-watt transmitter if about 200 volts are put on the plate, and a 50-watt valve will control a 250 transmitter.

The "ratio tap" circuit is due to Capt. P. P. Eckersley, well known to all British amateurs. The anode coil has a very large number of turns of fairly thin wire, and the aerial coil is wound right on top of this. The grid coil is coupled in the usual way. This circuit enables an aerial to be worked on a wave nearer its fundamental than any other circuit not using a series condenser. The anode coil for 200-metre work should have a natural wave-length of 400—600 metres.

The Aerial Inductance.

We now have a choice of circuits to select from. Personally, I would recommend the Colpitts for simplicity and efficiency, followed by the master oscillator, whose advantages are very great, although it is hard to work. However, the choice must be left to the individual experimenter. As regards the

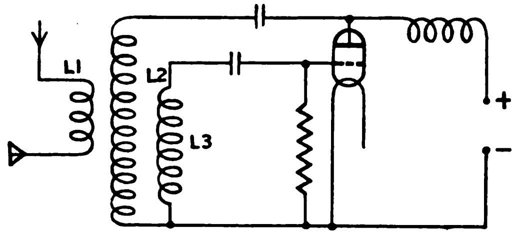


Fig. 9.—In the ratio tap circuit, the aerial coil L1 is wound over the anode coil L2, consisting of many turns of fine wire.

set, the best procedure is to build it up on a large table, keeping the wiring spaced very well—far more than in a receiver. The aerial coil should, if possible, be of very large diameter—up to 18 ins.—and wound with aerial wire, turns spaced half an inch or so. Twenty-five turns on a hexagonal frame of ebonite rod, spaced $\frac{1}{3}$ in. on an 18-in. diameter is a suitable size to commence with. The grid leak is another important thing. This must be variable. It may conveniently be a small column of water in a glass tube with movable electrodes. The careful adjustment of the grid leak is a great aid to efficiency. The anode tap is also of vital importance. The anode coil will, on 200 metres, be larger than the aerial portion, and must be adjusted for best results. The more anode coil in circuit the lower the input falls, but, of course, at a

certain point the aerial current falls as well. Just before this point is the most efficient position of working. At this position we have the aerial impedance and the anode circuit impedance equal, which means we have the best transfer of energy. It is an advantage to use as high an H.T. value as possible, and a consequently small current. An ordinary 30-watt valve will stand 1,500 volts comfortably on a 10 to 20-watt total input with astonishing efficiency if carefully adjusted, although theoretically the maximum allowable anode voltage is 1,000 volts.

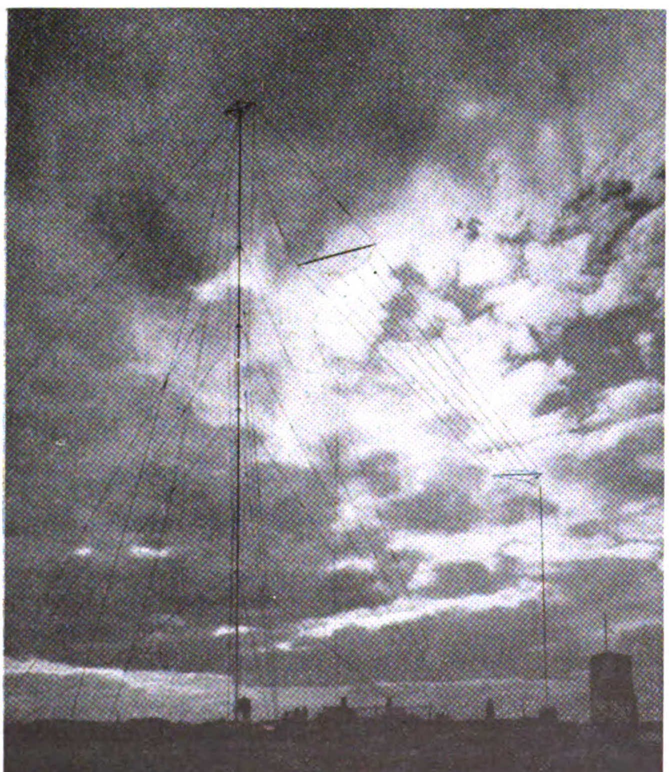
The most important points are these :—

(1) Use a counterpoise.
(2) Use a high H.T. voltage.
(3) Use a variable grid leak, as high a value as possible.
(4) Use a variable anode tap, as high a value as possible.

I hope these notes will enable many to make their sets more efficient and so obtain greater ranges than before. If we get to Holland, Scotland and Spain on ·3 to ·5, we can look forward to getting to the U.S.A. on our efficiently radiated 10 watts in the winter.

At some future date I hope to discuss some of these points more fully than is possible here. Experiments, such as the measurement of radiation resistance, should be carried out by every amateur, and many would be considerably surprised to see their aerial curves.

Finally, I would emphasise the need of a great deal of experimenting before good results can be expected. Your first receiver was not the last word in efficiency, so don't expect your transmitter to be so the first time you fit it up.



The accompanying photograph illustrates the new antenna system which has just been erected at the WGY broadcasting station. The aerial contrasts greatly with those of our own broadcasting stations which employ a cage type. The flat top aerial seems to be used more in America than here, although many experimenters now employ the flat top for transmission purposes.

The Design and Operation of Tuned Anode Receivers.

By Captain ST. CLAIR-FINLAY, B.Sc.E. (Laus.),

Late Chief Experimental Officer Research Commission, Technical Adviser Inter-Allied Technical Council.

THE following notes upon a practical receiving circuit for general amateur use deal primarily with a system of radio-frequency amplification, the principle of which is, of course, well known and widely used in one form or another, and the particular form about to be described, first used by the writer in connection with short-wave work in the relatively early days of valves, is now given in no sense as a novelty, but as an outcome of more recent development along these earlier lines towards a really practical and efficient receiver for medium and short-wave work, which it is hoped may be of interest to experimenters, to whose purposes it is particularly suitable.

It is termed by the writer a duo-regenerative circuit, and the principle upon which it is based is the reactance-capacity—or, as it is, perhaps, better known, the tuned anode—method of radio-frequency coupling, one that has been the subject of much booming, use, and, unfortunately, ill-use of late in connection with broadcast reception; but if readers of the present article will try to forget its "barrel organ" guise, and will consider it for a moment from the scientific standpoint, they will—if they have not already done so—find in it much of at least potential interest and use to them.

To begin with, it is one of the most efficient known methods, and probably the most practical method, of radio-frequency coupling for medium and short wave-lengths below, say, 2,000 metres (*i.e.*, the band with which amateur experimenters are chiefly concerned), though this by no means represents the limits of its utility; and over this band, down to very short waves, and particularly including short waves, possesses properties of special value, the degrees of amplification and selectivity obtainable and the general practicability of the system being of a high order, whilst the instability commonly attributed to it is largely a chimera due for the most part to imperfect application of the principles involved; and it is the purpose of these notes, firstly, to discuss these principles in general terms and to suggest how best they may be applied for the avoidance of such pitfalls; secondly, to describe a particular form of circuit that has proved particularly satisfactory in practice; and, thirdly, to indicate the results obtainable with such circuit.

The principle of operation of the tuned anode is probably well known to the majority of readers of this journal, but, to make what follows the clearer, it may be well—without entering into unnecessary technicalities—to touch upon this briefly first of all.

The "tuned anode" is simply a resonant rejector circuit excited by incoming high-frequency currents, just like the aerial circuits itself, except that the currents have first been amplified by passage through the valve to which the anode belongs and are, therefore, able to excite this second tuned circuit more strongly than the aerial circuit was excited by the original unamplified currents.

The strong excitation of this second circuit gives rise to increased potential differences across the inductance therein, which are passed on to the grid of another valve for repetition of the process or for rectification or both, the function of the valve thus being current amplification and of the tuned circuit, the conversion of this into voltage amplification, the inductance acting as an auto-transformer. In fact, this arrangement is sometimes known as auto-transformer coupling, and the difference between it and transformer coupling is the same as that between choke and transformer couplings in audio-frequency circuits, and the principles involved are the same, both forms of auto-transformer or "choke" operating on the principle of self-induction.

Now a comparison between tuned anode and transformer coupling will show them to be identical, except that the actual inter-valve coupling itself is in the latter case inductive or magnetic, whilst in the former it is static, and herein lies the great practical difference that, whereas in the one case an extra tuned circuit is necessitated for full efficiency, in the other it is not, and this is where the tuned anode method particularly scores. In fact, transformer coupling is nothing more nor less than a tuned anode to which is added another circuit simply for intervalve coupling purposes, some break in the electrical continuity of the intervalve circuit being, of course, necessary so far as the continuous current component therein is concerned so that the high-tension battery potentials shall not be impressed directly upon the grid of the valve, and, in view of the popularity of transformer coupling amongst amateurs, it may be as well to examine both systems in order that their relative advantages may be compared.

The simplicity of the tuned anode as compared with transformer coupling is obvious and will not be questioned, and it remains, therefore, to consider whether or not the extra complexity of the latter is justified by attendant advantages.

First, there is the question of amplification, as to whether the addition of the extra circuit should result in any material increase in this. Since the potentials across the secondary circuit will, other things being equal, depend (*a*) upon those in the primary; (*b*) the induction ratio between primary and secondary; and (*c*) the transformer losses, it follows that a step-up effect will be obtained only if the secondary-to-primary induction ratio is made large enough to overcome the transformer losses without the primary potentials being at the same time reduced; and since in a tuned circuit the available induction is governed by the resonance frequency, and this will, of course, be the same in both circuits, it is evident that no material step-up effect between them can be looked for.

It might be thought that this could be arranged by reducing the induction in the primary circuit and increasing the capacity therein to arrive at the same frequency, whilst doing the reverse in the secondary circuit, but, unfortunately, electricity refuses to be "wangled" like this, and the plan does not answer in practice because reducing the primary induction also reduces the initial potentials, and this completely discounts the step-up effect gained, on the principle that 1×4 has the same result as 2×2; and, in fact, the result in this case is not even quite "as you were," since, whilst the reduction of induction and increase of capacity reduces the efficiency of the primary circuit as shown, the reverse process reduces that of the secondary also by reducing its periodicity and thereby flattening out its potential peak, this aperiodicity moreover making strict resonance of the circuit impossible and thereby impairing its selective properties.

In practice, therefore, no material gain in amplification is obtained by the addition of a secondary intervalve circuit, tuned or otherwise.

Then there is the question of selectivity. A tuned anode constitutes, as has been shown, a resonant high-frequency choke, *i.e.*, an efficient rejector of the desired oscillations which produce excitation of the circuit and are shunted off in their entirety and in amplified degree to the grid of a following valve, and a more or less efficient acceptor of undesired oscillations which do not produce excitation of the circuit and are not shunted, but pass through the circuit and away to earth. A certain proportion of these do, of course, reach the grid of the next valve together with the desired oscillations, but, whereas these latter have been amplified by the action of the circuit, the former have not, so are comparatively greatly suppressed. The percentage of undesired signals that will reach the grid of the following valve, other things being equal, will depend upon the high-frequency resistance or damping of the rejector circuit, and will only approach zero if the damping is zero, a condition which does not naturally obtain, but which can fortunately be approached in practice by the introduction of reaction into the circuit, which counteracts the effects of damping therein and enables the selectivity of the circuit to be greatly increased.

Now, in considering the question as to whether the addition of a secondary circuit—*i.e.*, the conversion of the simple tuned anode into transformer coupling—may be

expected materially to increase this selectivity, it must be appreciated that the currents flowing in the primary will be not only those due to the desired signals, but also those due to the undesired signals on their passage through the circuit in its function of acceptor thereof, so that transference of the desired signals from primary to secondary will, to some extent, be accompanied by transference of undesired signals also, the extent depending chiefly upon the degree of aperiodicity of the circuits. If the aperiodicity of either or both circuits is at all considerable, as is the case when neither or one only of them is closely tuned, the proportion of undesired signals reaching the grid of the next valve will be considerable also, and the selectivity of the arrangement proportionately poor, whereas if both circuits are in strict resonance the selectivity will be good because neither will respond at all readily to undesired oscillations and the transference of these will be small. But here, again, the effects of resistance in the circuits must be taken into consideration, as unless the damping be reduced by the introduction of reaction neither circuit will be sharply resonant, the selectivity in this case being certainly not superior, if as good, and the amplification considerably inferior to that obtainable with the tuned anode with reaction, which is the simpler arrangement.

It will, therefore, be clear that transformer coupling has for our purposes no real advantage to offer over the tuned anode method unless reaction is applied, in which case a material—though not enormous—improvement in selectivity is certainly to be expected. But the introduction of this, of course, still further complicates the arrangement as compared with the tuned anode, and it is questionable whether, from the experimenter's standpoint, the resultant gain is at all worth the loss of handiness involved.

Practicability is, after all, one of the first and foremost essentials of the "standard" receiver of an experimental station where the wave-lengths received are continually varying. Complex arrangements involving a multiplicity of tuned circuits, etc., are all very well in the case of commercial or other stations operating on fixed wave-lengths, but are of little practical use in experimental stations where continual searching and tuning are the rule. Here conditions are quite different, and it does not suffice for a receiver to be highly sensitive and selective if its tuning arrangements are so involved as to make searching with it a labour of frightfulness.

There is, of course, much interesting and useful experimental work to be done in the field of reception, but this concerns the present article only insomuch as the more this is done at any given station, the more need will there be at that station for a practical "standard" receiver against which results may be compared, and with which ordinary tests and receptions may conveniently and reliably be carried out; and for this purpose the best type of receiver will manifestly be that which best combines the essential qualities of practicability, efficiency and dependability.

This the tuned anode undoubtedly does—or, at least is capable of doing—and it is the purpose of these notes to show not only why this should be so, but how it may be made so.

The actual circuit proposed will presently be described, but first of all it is desirable to deal with the pitfalls so that these may be avoided from the start and success be assured.

The most far-reaching of these lie in capacity-effects, upon which too much emphasis cannot be laid. Applicable as this, of course, is to all radio-frequency circuits, it is—as the very name implies—particularly so to reactance-capacity circuits, the success or otherwise of which are virtually bound up with this issue.

The golden rule is, in a nutshell—from beginning to end and throughout, from antenna to earth, and particularly in the receiver itself, avoid stray capacities as you would the plague.

This will, of course, be a matter chiefly of careful wiring arrangements and the avoidance of overcrowding of parts and circuits, and will be made clear by reference to Fig. 1, showing the capacities and couplings inherently existant in a valve and its associated circuits.

These may be said to comprise three separate but interacting capacities: X between the plate and grid of the valve and any leads attached thereto; Y between grid and filament and leads; and Z between plate and filament and leads. (See Fig. 1.)

Y and Z are small so far as the electrodes themselves are concerned, but begin to become appreciable where the leads come close together at the pinch, legs and sockets of the R-type of valve, and may become considerable if the wiring concerned is allowed to run close together or close to any other conductor, earthed or otherwise, in the receiver, the effects being to cause high-frequency losses in the plate and grid circuits and to reduce the natural frequency of these circuits so that, to counterbalance this, the inductance thereof has to be cut down for any given wave-length until for short waves insufficient induction will remain to produce the required potential differences in the circuits, the result being both loss of efficiency and limitation of the effective wave-band range of the receiver.

But more important still is the plate-grid capacity X, which, unfortunately, owing to the proximity and comparatively large size of the electrodes concerned, is the largest of the capacities within the valve itself, and is, of course, also subject to aggravation at the pinch and legs of the valve before we even get to the wiring of the receiver.

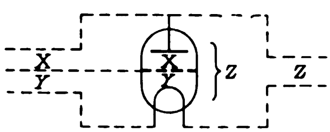


Fig. 1.—Illustrating the various capacities existing between the electrodes.

It is this capacity or coupling that is the most prolific source of trouble unless specially guarded against, as not only can it cause range limitations and high-frequency losses like Y and Z, but is also chiefly answerable for the bugbears of uncontrollable self-oscillation and general instability in such circuits for which, woefully common as they are, there is, in reality, no necessity at all.

Fig. 2, showing the tuned anode circuit with two forms of regenerative coupling, one of which will be recognised as inherent to it, should make this clear, in that it shows it to be nothing more nor less than a straightforward and fully-fledged self-oscillation or generative valve circuit adapted to reception instead of transmission purposes, requiring only a sufficiency of either capacity (Fig. 2A) or inductive (Fig. 2B) coupling between the plate circuit L2 — C2 and the grid circuit L1 — C1 to become an active generator of continuous oscillations when these two circuits are in resonance; and since in practice they will, of course, be tuned to resonance, and an appreciable degree of coupling between them will exist inherently within the valve itself, it is not difficult to see where the danger lies or how it arises. It lies, of course, in any stray couplings the sum of which may so increase the inherent coupling as to give rise to persistent self-oscillation or an uncontrollable tendency thereto, thus making the receiver unstable and spoiling it for the reception at least of telephony, and arises (if allowed to do so) from malarrangement—from the scientific standpoint —of the receiver in general and of any wiring concerning the plate and grid circuits of the radio-frequency and rectifying valves in particular.

But the danger need not arise and its prevention is not difficult, although, strange to say, it does seem to be allowed to arise in more or less unnecessary degree in four cases out of five, frequently unknown to the operator, or at least unrecognised by him, because it is insidious and may not openly declare itself unless so extreme as to be obvious. In that case self-oscillation troubles, etc., will make their existence painfully evident, but up to that point the little instabilities, wave-range limitations, amplification, selectivity, sensitivity and general efficiency losses that are really going on *sub-rosa* may not be realised, and the operator may believe his receiver to be working quite well, simply because it functions without obvious shortcomings to open his eyes and he has no standard whereby to gauge its true capabilities. But let him compare it against such a standard, *viz.*, a similar receiver really scientifically designed and constructed, and what a tale will be unfolded!

The secret—if such it can be called—lies in *designing* the receiver before constructing it, in such a manner that stray capacities and couplings of any kind shall rigorously be reduced to a minimum, to which end particular attention should be directed to :—

(1) Arrangement of the wiring so that all leads—particularly those concerning plate and grid circuits—shall be as short and as widely separated as possible, both from one

another and from all other conductors, and the terminals, etc., concerned as far apart and isolated as possible.

(2) The use of coils, fittings, etc., of minimum self and incidental capacities.

(3) The use of low-capacity skeleton (air-spaced) type valve sockets and small nuts or threaded sleeves of ebonite, fibre or prepared wood in place of the usual metal nuts for their attachment to the panel; or preferably valves and holders of the anti-capacity type (not merely adapters plugged into ordinary sockets) if short-wave work is contemplated.

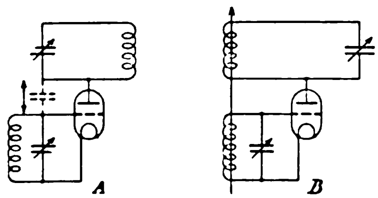


Fig. 2.—Illustrating the coupling between the grid and anode circuit.

(4) The use of low self-capacity and low resistance wire for all wiring and windings, such wire being preferably stranded, of reasonably generous gauge, and either air-spaced or covered only with cotton or other suitable insulator of low specific inductive capacity.

(5) The judicious use, particularly for short-wave work, of screening of any parts of the radio-frequency circuits likely to be subject to body or other stray capacities difficult of avoidance—such, for example, as tuning condensers, which should be earth-screened and provided with anti-capacity control handles.

And now for two important *don'ts* and a corollary :—

(6) Don't incorporate a complex system of jacks, plugs, switches, etc., on the radio-frequency side of the receiver—even of so-called " anti-capacity " type. These are all very well for audio-frequencies, and it may be very neat and convenient to be able to throw valves, etc., in and out of circuit by mere touch of a switch, but where radio-frequencies are concerned such conveniences invariably have to be paid for—often dearly paid for—in terms of far more important stability and general efficiency. It is an axiom in radio-frequency circuits that all wiring and connections therein should be as simple and straightforward as possible.

(7) Don't attempt to make a tuned anode receiver of the waistcoat-pocket type; do not squeeze it into a small space or cramp it in any way, but allow plenty of room for adequate spacing and proper arrangement of everything.

(8) Finally, and in fine, do not in any way sacrifice *efficiency* for mere neatness of appearance or convenience; reconcile all three as far as possible—a well-designed receiver usually will look workmanlike—but let this be quite an incidental consideration and efficiency always the foremost.

In fact, give to the design and construction of the receiver the same meticulous care and consideration that you would to a low-power transmitter in which little leakages and inefficiencies cannot be afforded. They can still less be afforded in a receiver, and all trouble taken for their avoidance will be amply rewarded.

It may here be remarked that all recommendations and the majority of comments made in these notes in reference specifically to tuned anode coupling apply equally—in some cases even more vitally—to transformer coupling, and, indeed, to radio-frequency circuits of any kind, the tuned anode not being specially more delicate or susceptible—with certain reservations mentioned—than most other systems.

It is not, of course, suggested that observance of the few simple rules given is all that is necessary to ensure complete success with reactance-capacity or any other system; but it will be so great a part of the battle that the foundations at least of a thoroughly efficient and satisfactory receiver will have been laid, and we can now go on to discuss the proposed circuit itself without doubt as to its complete success in practice.

The basis of this circuit is shown in Fig. 3, and will be seen to be a straightforward tuned anode circuit with reaction (shown coupled to the A.T.I. for simplicity) arranged in a not unorthodox but, in practice, somewhat unusual way, the whole constituting, as it stands, an autodyne receiver for C.W. and simple regenerative receiver for telephony which should be regarded for the present purposes as one unit, the reason for which will presently become clear.

The considerations underlying the reaction arrangement shown are :—

(1) That since the tuned anode or plate

circuit of the first valve V1 will in any case include an inductance L2 and condenser C2 for tuning purposes, it may as well be utilised to furnish the desired regeneration on the aerial circuit simultaneously with its ordinary functions, which it is able to do without loss of efficiency in any respect, thus saving an extra reactance and, perhaps, tuned circuit for this purpose, and considerably simplifying the arrangement both as to construction and operation.

(2) That the reactance thus constituted, being tuned, is of the most efficient type.

(3) That regeneration is by this means introduced directly into the aerial circuit and the grid circuit of the second valve V2 simultaneously, which is not fully possible with the usual arrangement in which the reaction onto the aerial circuit is derived from the plate circuit of the detector, although it does, of course, benefit to some extent indirectly through being in train.

(4) That for heterodyne reception it is preferable that the oscillating valve be, if possible, purely a radio-frequency valve and should not combine a different function such as rectification, whence it is better that regeneration should, for this purpose, be as derived from the H.F. valve V1 itself, and not from V2.

Now such a circuit, although its use with an outside aerial is not permissible during broadcasting hours owing to the fact that oscillation of V1 will, of course, energise the aerial, constitutes a very efficient receiver for both C.W. and telephony, and has the advantage of extreme simplicity; in fact, there being but the two tuned circuits L1—C1 and L2—C2 and the coupling between them to consider, it is as simple to operate as the majority of single-valve and even crystal receivers, though its sensitivity is, of course, much greater, whilst for heterodyne reception of short waves it could scarcely be bettered, being quite as efficient as a normal separate heterodyne.

For the reception of telephony in particular, however, this circuit, good as it is, is capable of improvement in certain respects, the first of these being selectivity. It will be found, as it stands, quite selective enough for most practical purposes where relatively weak signals are concerned, the tuning, in fact, being decidedly sharp with such, thanks to the rejector circuit L2—C2 and the regeneration introduced thereby, but for very strong signals, such as those from broadcasting or nearby transmitting stations, there is certainly room for improvement. Secondly, its sensitivity can be still further increased to a very material and useful extent. And, thirdly, provision can be made to permit of its use with regeneration during broadcasting hours. And all three of these important improvements can be obtained without materially complicating the arrangement in any way.

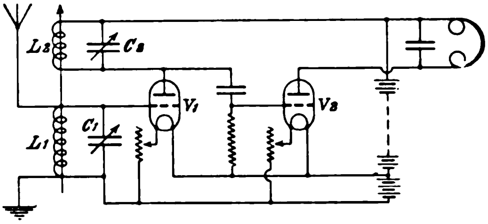


Fig. 3.—The basic regenerative tuned anode circuit.

This development is shown in Fig. 4, and will be seen to consist of the introduction of an additional (untuned) reaction circuit L3 from the plate of the detector V2 on to the anode circuit L2—C2 of the first valve, by means of which the high-frequency component in the former—otherwise useless—is utilised to introduce reaction into its own grid circuit, thus completing the regeneration train and causing the detector V1 to function also as a second radio-frequency amplifier with considerable efficiency, and enabling reaction to be applied to the aerial and rejector circuits L1—C1 and L2—C2 independently.

The objects of this are threefold, *viz.* :—

(1) To permit of intervalve reaction during broadcasting hours, when, of course, the aerial reaction provided by the first valve cannot be used.

(2) To enable *both* V1 and V2 to be brought to that point immediately preceding self-oscillation where, owing in effect to steepening of the normal characteristic curve, abnormal sensitivity obtains.

(3) To provide against unbalance of the two circuits which, owing to inequality of their inherent damping, ordinarily results in the damping in one of them being reduced to zero before an equal condition is obtained in the other, self-oscillation thus setting in considerably before maximum sensitivity

can be attained, this being an inherent weakness in most reaction circuits. Now the introduction of reaction independently on to both L1—C1 and L2—C2 enables the damping in both parts of the circuit to be reduced to zero or thereabouts simultaneously and the full benefits of regeneration to be obtained in either or both circuits independently or simultaneously as desired up to the point of self-oscillation of either valve, thus enabling maximum efficiency to be obtained.

The increase of sensitivity resulting from this arrangement may be in the neighbourhood of as much as 50 per cent. over that obtainable with the single reaction circuit of Fig. 3, whilst the improvement in selectivity is such that a closed aerial circuit becomes for most practical purposes quite unnecessary, and is therefore dispensed with in Fig. 4, thus maintaining the simplicity of operation of the circuit as a whole. In fact, it will be seen that, since L3 need not be tuned, little or no extra complication is introduced thereby, and there remain only the two tuned circuits L1—C1 and L2—C2 and their couplings to consider.

Some doubt may be felt concerning the absence of a closed aerial circuit, but it should be borne in mind, firstly, that the use of such with direct reaction is just as restricted under P.M.G. regulations as is a similar arrangement with open circuit, and secondly, that loose coupling is merely one way of obtaining selectivity—neither the only nor necessarily the most efficient way.

The arrangement of Fig. 4 will, in practice, be found fully as effective in this and all other respects as a closed reaction circuit, the use of which is, in fact, not recommended with it, owing, firstly, to the unnecessary extra complication involved; and, secondly, to its liability to cause a tendency to instability and undesirable self-oscillation in this connection.

And now we have touched upon the one weakness of the Fig. 4 circuit, *viz.*, a slight tendency to instability and consequent trickiness in operation which may in practice sometimes prevent full realisation of its virtues in other respects, and the overcoming of this in a simple and effective manner is a further and last improvement which our quest for efficiency and practicability calls upon us to make.

This final development is shown in Fig. 5, which shows the complete receiver advocated in the present article, and will be seen to consist of provision for control of the plate voltage and grid potentials of V1 and V2 in a simple and straightforward manner, which has the further advantages, as compared with the usual potentiometer methods, that neither is undesirable resistance introduced into the circuits, nor is any extra drain imposed upon the filament battery.

By this means the respective and relative plate, grid, and filament potentials are readily adjustable, so that any tendency to instability disappears and the maximum sensitivity, amplification and general efficiency become reliably obtainable; and there now remain to be given only a few general hints as to the practical working of such a receiver which may prove useful.

The complete circuit of Fig. 5 is that actually installed at the writer's station, and is shown with one stage of note-magnification V3 and one stage of power amplification V4; but for clearness, without switchgear, the actual arrangements and number of stages used on the audio-frequency side will,

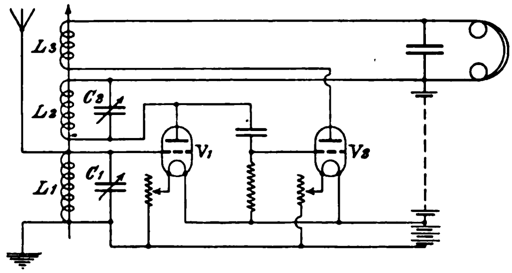


Fig. 4.—This circuit enables both valves to be brought to the point of self-oscillation.

of course, depend entirely upon individual requirements. Certain constants are, however, given, which, it is recommended, be followed reasonably closely.

With regard to inductances, for short-wave work with this receiver the writer rather favours variometer tuning for L1 and L2, preferably shunted by vernier condensers of about ·0001 mfd., provided the variometers are really well designed and constructed, and for medium wave work above 500 metres plain cylindrical coils of about 2½ to 3 ins. diameter, tuned with variable condensers of about the values shown in Fig. 5, and preferably untapped for the avoidance of

dead-ends. Basket coils will be found very efficient similarly employed, and, where it is desired to cover a considerable wave-band conveniently, duolateral or honeycomb inductances of the plug-in type will be found quite suitable, though scarcely as efficient as the foregoing owing to their somewhat greater self-capacity due to their coverings and their plugs and sockets. Similar coils with gimbal mounting are better, and can be used very satisfactorily. Slab and such-like coils are not recommended owing to their relatively high self-capacity. The reactance L3 may be of any desired type, according to circumstances, the plug-in type being very convenient owing to the ease with which the size of coil may be changed, and this will be found of considerable importance in practice.

As to valves, the R type may be used quite satisfactorily down to about 150 metres, but below this anti-capacity valves, such as the Ora B. or V.24 are desirable—and for really short waves essential—on the H.F. side (including detector), though the four-pin type may, of course, always be used for L.F. amplification. A Mullard P.A. type is suitable for power amplification, as it works well on a 6-volt filament battery.

A special rectifier, such as the R.4B., whilst not essential to good results, is capable of markedly increasing the sensitivity of the receiver, and is recommended; whilst if grid-leak rectification is employed a variable compound leak, as shown in Fig. 5, will be found of advantage, though by no means essential.

Low-temperature valves may be used very satisfactorily with this receiver.

The A.T.C. will usually be found best in parallel with the A.T.I. above about 300 metres and in series below, though this will, of course, largely depend upon the size and type of aerial in use.

The loading ratio is of considerable importance, and should preferably be not less than ·5 nor much greater than 5, *i.e.*, the natural wave-length of the antenna should be somewhere within the limits of about ·2 and ·7 of the wave-lengths to be received, and this is usually within the bounds of feasibility where short waves are concerned, but is, unfortunately, not so, particularly with restricted amateur aerials, on the longer waves, which provides one reason for the falling off in efficiency of reactance-capacity circuits where the latter are concerned.

For this reason single-wire aerials up to maximum P.M.G. dimensions are to be recommended for short-wave reception below, say, 400 metres and multi-wire aerials for the higher lengths, a sound general rule being the higher the wave-length the greater the number of wires permissible and of advantage in the antenna, always maintaining due regard to other considerations which will be known to readers of this journal.

Now the operation of such a receiver will be found quite simple, and really no more difficult or tricky than an ordinary closed-circuit single-valve reaction set, though the results obtainable will, of course, be immeasurably superior. The number of tuned circuits and couplings—two only—is the same, the necessary adjustments are neither many nor unduly critical, and the set will be found easily manageable and highly efficient throughout its range. In fact, in the writer's considered opinion, it is questionable whether, valve-for-valve and adjustment-for-adjustment, any circuit now in common use can offer much real general advantage over that of Fig. 5 for amateur use.

Compared with transformer coupling, for example, the sensitivity will be found about 25 per cent. greater, valve-for-valve, than fully-tuned transformers with reaction, the selectivity quite comparable, whilst the simplicity of operation is, of course, much greater.

For reception during broadcasting hours on an outside aerial it is necessary only to loosen the coupling between L1 and L2 and to tighten that between L2 and L3 somewhat to obtain a form of intervalve reaction which is effective but innocuous (so far as any form of reaction can really be innocuous), whilst at other times full dual regeneration is available simply by using both couplings at once, or for the reception of C.W. L3 is loosened somewhat and L1 and L2 tightened until V1 oscillates.

The regeneration due to L3 is, of course, variable both by the degree of coupling and by the size of coil used, and it will usually be found that for short waves L3 may be somewhat the largest of the three, whilst for longer waves it may be the smallest, or about the same size as L1. Self-oscillation

of V2 should be avoided, though it will be found possible to receive C.W. in this manner, for example, during broadcasting hours when the signals are coming in on a length adjacent to the broadcast band.

The best way to tune in telephony signals will usually be to start with fairly loose average couplings between the three coils until the signals have been brought in by adjustment of the two tuning-condensers and then to tighten first one coupling and then the other, slightly resetting the condensers meanwhile, until the desired signal strength is attained, the same applying selectivity is obtained by loosening the couplings generally to the accompaniment of reduced signal strength, in that it is here obtained by increasing the degree of regeneration and resultant resonance, *e.g.*, tightening the couplings, which results in increasing the strength of the desired signals to the suppression of those that are not desired—a more efficient principle.

Should any tendency to undesired self-oscillation occur when the couplings are not particularly tight, this may be corrected by adjustment of the grid-potential tap, so that this is made somewhat more positive—

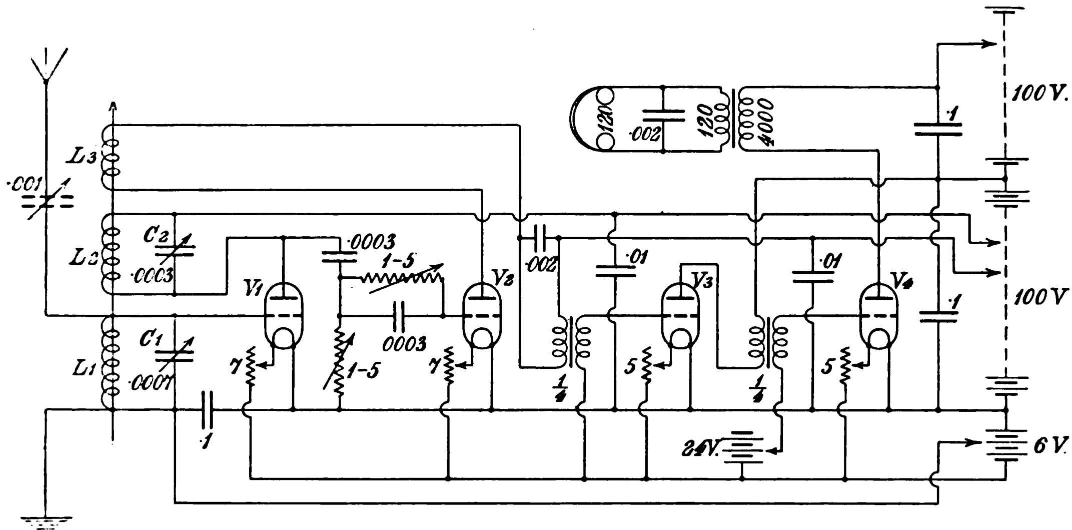


Fig. 5.—A practical regenerative receiver providing critical control of all variable factors. The last valve functions as a power amplifier.

when variometers are used, except that the initial tuning should be done on the variometers themselves and the subsequent fine tuning on the vernier condensers. Vernier condensers may, of course, be employed with advantage no matter what tuning system is used, and are actually included on the writer's set (though not shown on the diagram), but are not essential.

A useful feature of the circuit is the way in which undesired signals can be eliminated merely by variation of one or other or both of the couplings and subsequent re-tuning of the condensers, or *vice-versa*, without necessarily loosening the couplings or losing signal strength at all; and in this respect the circuit is quite different from the usual loose-coupled arrangement in which extra or, rather, less negative—of the anode voltage tap, and also, if necessary, of the variable grid-leak arrangement, if such is used, should the seat of the trouble be in the second valve.

Should a more marked tendency of this kind arise—as it sometimes may when the receiver is used towards the upper limit of its useful wave-range, or when a frame is used for reception above about 400 metres—it may be corrected by the use of a small stabilising plate on the common inductance L2, which may conveniently take the form of a ring or cylinder of spring brass or copper made to slip in and out of the inductance at will, and should preferably be earthed for maximum effect, the *modus operandi* of this arrangement being the closer equalisation

of damping in the aerial and first plate circuits, the latter of which is, of course, normally minus the stabilising action of the antenna-earth system, and is, moreover, subject to a double regeneration effect; and this will be found quite effective without resulting in loss of signal strength, since L2—C2 will now accept more regeneration without self-oscillation, and this can readily be provided by tightening the coupling.

The condition to be aimed at for best reception of telephony with this circuit is a nice regenerative balance between the three circuits L1—C1, L2—C2, and L3, so that the two valves V1 and V2 shall be as nearly as possible equidistant from the sub-oscillation point, and this may readily be obtained by judicious use of the adjustments provided. It is scarcely necessary to add that care must be taken in the first instance to make the connections to the three inductances the right way round, otherwise a degenerative effect will result and nothing will work to plan.

In conclusion, some indication as to the results obtainable with such a receiver may be found useful as a guide.

In the matter of selectivity it may suffice to say that Glasgow at 330 miles can always be received through Birmingham at 85 miles without interference from the latter, notwithstanding the considerable "jamming" power in use and the fact that their wavelengths are no more than 5 metres, or 1·2 per cent., apart; also the fact that Birmingham, being in a direct line immediately between Glasgow and the writer's station, reception is literally "through" him and directional methods are out of the question.

As to sensitivity and amplification, using two valves only the broadcasting stations can be brought in quite comfortably on the loud speaker up to a range of about 30 miles, the addition of one note-magnifier enabling this to be done on a frame, or increasing the range to about 50 miles. Three valves enable most of our 10-watt transmitters up to 40 miles or more, many of the more powerful Continental amateurs, and most of the British and Continental broadcasting stations to be brought in well on 'phones—some of them on the loud speaker—whilst some of our more powerful amateur transmitters come in quite strongly on the latter up to 30 to 40 miles. American broadcasting stations are often strongly audible on 'phones even in summer with three valves, whilst the volume obtainable with that number on our own broadcasting stations is sufficient to fill a good-sized hall up to about 30 miles.

Four valves do not often prove necessary except for long-distance and loud-speaker work, and as an instance of what may be done on this number may be mentioned the reception recently—in August—of W.G.Y., New York, at loud-speaker strength sufficient to fill a largish room; whilst, as further examples of the sensitivity of the circuit may be cited the reception during a recent low-power test of quite readable telephony on 180 metres from 5 BT at 30 miles when his input was stated as 2 milliamperes at 30 volts only (·075 watt) and radiation unmeasurable, and of speech on 200 metres from 8 BF at 300 miles, radiation 1·2 ampere, strength R 3–4 on an indoor aerial. And it should here be mentioned, firstly, that the circuit of Fig. 5 with one high-frequency valve only was used in each of these instances (the writer has not touched upon the question of additional H.F. stages in these notes simply because such are so very rarely necessary with this circuit, but, in view of the forthcoming transatlantic tests, etc., will hope to do so in a future article upon this subject); secondly, that the outdoor aerial used is of standard P.M.G. dimensions—60 ft. in length and 40 ft. in height; and, thirdly, that the reception conditions in each case were ordinary average summer conditions and in no way exceptional, the results given being probably reproducible on at least four days out of five throughout the year.

But perhaps the most convincing guide that the writer can give is the simple statement of fact that, whilst his own station—which is some distance out in the country, and therefore requires an efficient receiver—is equipped for short-wave work with a seven-valve super-heterodyne receiver, with which, of course, remarkably fine results are obtainable, quite three-quarters of his reception other than purely experimental work is carried out on the circuit of Fig. 5, the extra valves of the "super" being usually unnecessary, and therefore frankly wasteful.

An Armstrong Super-Heterodyne Receiver.

By E. J. SIMMONDS.

Super-Sonic amplification is, no doubt, the simplest and most efficient method of short wave reception. Not only does the circuit become easily manageable, but the selectivity of the receiver is increased considerably. In the following article will be found full data for the construction of a super-sonic amplifier.

THE theory of the super-heterodyne is simple, and the operation has many advantages. The principle difficulty in high-frequency amplification at short wave-lengths, namely, valve capacity, is overcome by the simple solution of reducing the frequency to some predetermined fixed value, when a radio-frequency amplifier designed for efficient long-wave working can deal with the signals.

The original signal is transferred to the closed circuit, and amplified at the original frequency. The local source of oscillations is coupled to the anode coil of the first high-frequency valve, and adjusted to such a value that a suitable beat frequency is formed, and impressed on the grid of the detecting valve. The resulting reduced radio-frequency oscillations are then passed to the long wave amplifier. By this method all the advantages of high frequency amplification at low radio frequency are obtained.

Now that increasing attention is being given to comparatively short-wave working, and in view of the difficulty and instability of ordinary receivers below 200 metres wave-length, it is thought that the description of a receiver embodying high efficiency, sharp tuning, absence of body capacity effect, and ease of adjustment will be particularly useful.

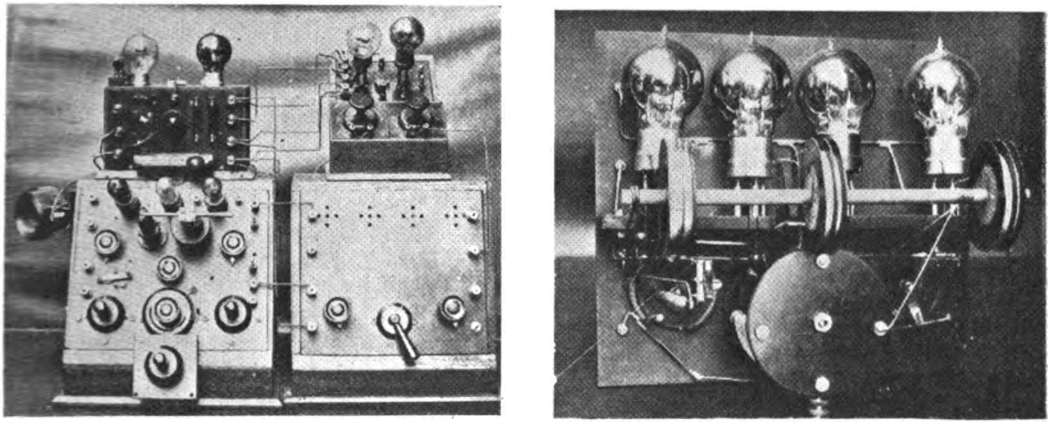


Fig. 1.—The left panel of the complete receiver contains the H.F., detector and oscillator valve and coupling device with the tuned anode coil. The right panel contains the three-stage long wave amplifier and detector. Above these are the H.F. and the detector (tuned anode, resistance or choke capacity) and two note magnifiers. On the right is seen the rear of the super-sonic amplifier.

It is proposed to describe a modification of the well-known Armstrong super-heterodyne as made by the writer for the Trans-atlantic tests of 1922, and used continuously since. It is worthy of mention that the instrument was only completed three days before these tests, and that, although unskilled in the adjustments, nearly 100 log entries were made, and 24 different U.S.A. amateurs scheduled complete with code words, in individual periods.

It should also be mentioned that no receptions were possible before 3.15 a.m. owing to "hash" from Northolt Radio, which source of short-wave interference is doubtless too well appreciated to call for more than passing comment.

The amplifier may consist of two units, the first of which is the ordinary one-stage

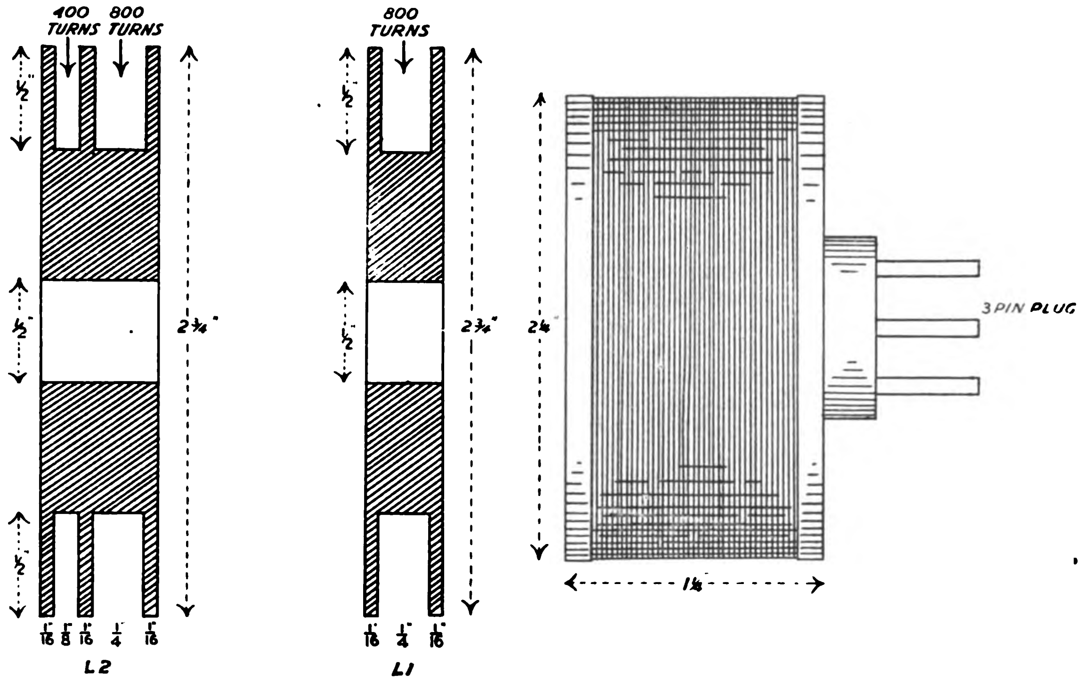


Fig. 2.—On the left are the coupling transformers. Three are required to the dimensions of L_2 and two as L_1, coupled closely together. On the right is the oscillator coil, two being required. One is wound with 30 turns of 24 D.C.C. and works from 140 to 450 metres, and the other is wound with 60 turns, the length being 2¼ ins.

H.F. and detector, plus the heterodyning valve and necessary coupling.

It is suggested that the tuned anode coil be of the air-spaced type to reduce self capacity, and for the same reason V.24 or other low-capacity valves may be used. In practice it is found convenient to use a separate H.T. battery of 36 volts with taps for the oscillator valve, and by varying this H.T. voltage it is possible to control the amount of energy transferred to the tuned anode without mechanically altering the coupling; there is also the additional advantage that this method does not affect the tuning. The oscillator coils are of the three-prong plug-in type, with centre tap to negative filament, a variable coupling being arranged between these coils and the tuned anode coil.

Those who have resistance-coupled amplifiers available may use these for the long-wave component with excellent results, but it is strongly advised that the inductively-coupled amplifier be used, as the efficiency of same is so much higher; the resistance-coupled type has also the disadvantage of requiring a higher voltage H.T.

The inductively-coupled type, however, requires more care in adjustment, and, if compressed into too small a cabinet, has the tendency to "couple back."

For those who contemplate making such an amplifier it is suggested that the valve holders be mounted about 6 ins. apart on a board, and then wired up temporarily.

When satisfactory operation is obtained, the question of compression into a cabinet can be taken up. Such step will, undoubtedly, have effects quite unforeseen. All necessary data can be obtained from the diagrams.

The formers for the H.F. transformers may be turned to dimensions out of hard-wood, well dried, and paraffin waxed, or may be built up from waxed cardboard.

They should be mounted on a common shaft of wood, all the coils being wound in the same direction. In connecting up, the two inside leads go to +H.T. and potentiometer slider respectively. Using windings indicated, the amplifier will be resonant at

about 4,000 metres, but the exact wave-length is immaterial so long as the frequency is not too high.

The plate circuits are aperiodic, but it is necessary to tune each grid circuit to the wave-length of the preceding grid circuit. It will be found that if the condensers are adjusted for uniform capacity, and the bobbin turns carefully counted, very little final adjustment will be necessary. This correction should be made after the amplifier is assembled and wired up. Slight changes then necessary may be made by varying the number of turns of the grid circuit transformers. The condenser C_2 is in the grid circuit of second valve, and should have a maximum capacity of ·0005. This condenser controls the regenerative action of the amplifier, and, as this capacity is reduced from maximum, the amplification will be increased up to the point of self-oscillation. This action will be found to be very smooth, with no "overlap," and under perfect control. It is advisable to try the grid leaks connected to +L.T. as well, as shown, as certain valves function better when connected to +L.T.

Any undesirable tendency to self-oscillation can be effectively controlled by the potentiometer, but the writer seldom finds it necessary to damp the grids, although the amplifier cabinet is only 12 ins. long.

This type of amplifier, when once properly adjusted, will continue to function perfectly as long as the H.T. and L.T. batteries are kept in good condition.

For all internal wiring use bare tinned copper wire bent to shape, solder all joints, and consider well the wiring scheme, especially with reference to the relative grid and anode circuits; small changes in wiring have far-reaching effects on all high-frequency amplifiers. Most of the receptions are done on a loop or small indoor aerial. If considered necessary, one or two note magnifiers may be used after the last detecting valve.

After completion the set should be calibrated. Connect up to aerial and earth as usual, and loosely couple a wavemeter to the aerial circuit. Now adjust aerial condenser, closed circuit, and tuned anode condensers, also heterodyne condenser for maximum signals. (Signals will be heard at two different settings of heterodyne condenser.)

Note should be made of the wave-length as indicated on wavemeter, and a chart should be prepared with columns for various condenser adjustments.

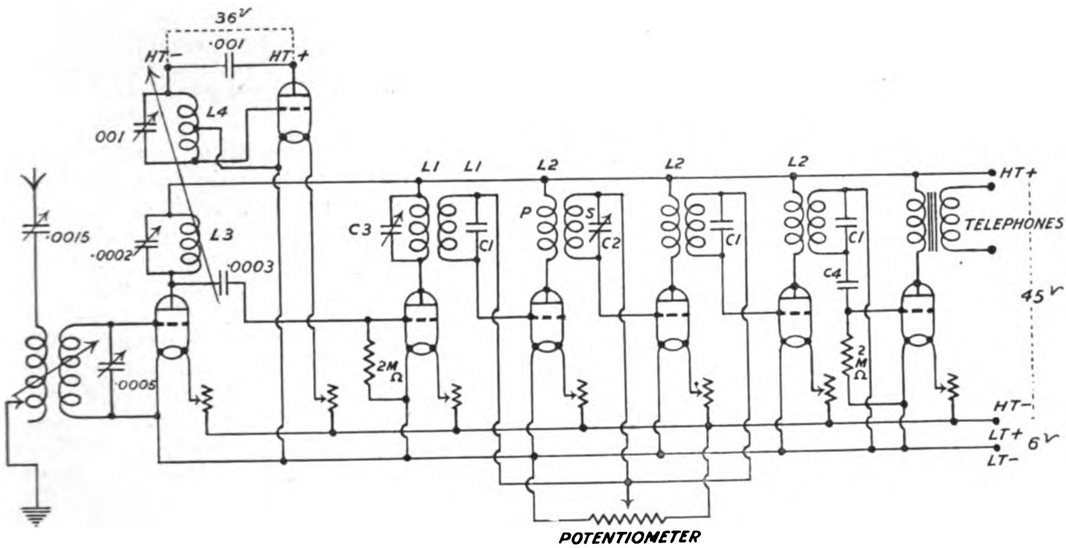


Fig. 3.—The complete circuit of the receiver in which the values are as follows :—C1 0·0001 mfd., C2 0·0005 mfd., C3 0·0002 mfd., C4 0·0003 mfd., L1 800 turns 36 D.S.C., L2 Primary 400 turns, Secondary 800 turns, 36 D.S.C., L3 Tuned anode coil, L4 Threepin plug-in oscillator coil.

This should be tabulated to cover the whole range of the receiver. By this means the maximum results may be obtained on any setting with ease.

It should be noted that the instrument so calibrated may be operated on any aerial suitable for short-wave reception, the only unknown factor being the tuning of the aerial. Although the adjustment appears to be complicated, in practice it is not so, and the writer finds the circuit particularly adapted to quick search.

Crystals and Crystal Testing.

BY A. V. BALLHATCHET, M.J.INST.E.

The introduction of the thermionic valve had the immediate effect of diverting the attention of the experimenter from the crystal, and since that time little investigation has been conducted. Below will be found a brief summary of the properties of various crystals and the methods used in testing.

THE enormous development of wireless telegraphy and telephony during the last two years or so has brought the crystal as a rectifying detector into great prominence. The crystal, in common with other examples of scientific achievement, suffered the fate of eclipse by a more brilliant rival, and that before its possibilities were fully determined. How many of my readers recall the Nernst electric lamp? This, a wonderful development in artificial lighting, when just reaching popularity, was eclipsed by the metal filament lamp. So the crystal as a rectifier of oscillatory energy has suffered partial eclipse by the thermionic valve. To many amateurs in wireless reception the crystal is a new thing, discovered simultaneously with the perfection of wireless telephony and broadcasting. Yet some of the older amateurs who, like the writer, experimented with coherers will remember what a revelation was their first reception with a crystal detector.

In spite of the wonderful things accomplished by the thermionic valve, and the promise of yet more wonderful things, it must be remembered that, as a detector, the crystal is in some respects vastly more efficient than the valve; and it is the fact that so little of the action of the crystal is known with certainty that renders it an object well worthy of prolonged and patient investigation by the seriously-minded amateur. It is largely the object of these few notes to awaken the interest of amateurs to the study of the crystal.

The Action of a Crystal.—It is held, generally, by those who have read a little of the theory of the subject that a crystal functions as a rectifier by reason of its unilateral conductivity; in other words, it possesses the property of allowing electrical energy to pass through it in one direction only. This is hardly correct, however, for practically all crystals will allow current to pass either way, only that the conductivity in one direction is very much greater than that in the other. So great is this difference that we may regard the lesser as being negligible. Careful experiments have shown that the half oscillations passed by a crystal are very distorted when compared with those passed by a valve when functioning as a rectifier. But the unexplained fact remains that a good specimen of crystal, properly adjusted, produces louder signals than the valve, and in many cases these signals are of purer tone. In this direction, then, the crystal is more efficient than the valve. Again, before a valve can function it must be supplied with current, and this is not by any means a negligible quantity—several watts even in the latest forms. But what percentage of this applied energy is returned? The crystal passes practically all the energy applied to it from the aerial circuit, the only loss being that due to its natural resistance. So that here again the crystal is far more efficient than the valve, for economy is surely a large factor when determining efficiency. Most readers who have studied the action of their crystal detector will admit that the most difficult matter in its adjustment is the *pressure* at the point of contact. This leads to the supposition that it is a matter of thermal effect which causes

the crystal to function. It is quite possible to take two pieces, say of galena, from the same large lump. One will act splendidly, while the other is either very poor indeed or absolutely worthless. Yet chemical analysis will show no difference ; the optical properties of the two pieces are identical, and other physical examinations will show no difference. Where, then, lies the difference in their behaviour when used for rectification ? This is the one great question yet to be answered.

The Nature of Crystals.—The majority of crystals used are crystalline specimens of natural metallic ores. In the early days of crystal detectors relatively few substances

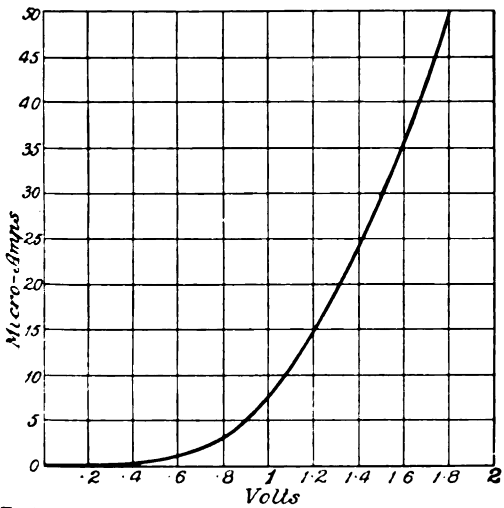


Fig. 1.—Characteristic curve of carborundum and steel combination.

were employed, and search for further suitable material was checked by the development of the valve. The recent boom in wireless reception has stimulated experiment and search, and it is now possible to compile a long list of crystals, and it is also perfectly safe to say that this list is far from complete. The following list comprises some of the specimens with which the writer has experimented, and the names given are the usual mineralogical terms. When a substance is known by more than one name the synonym is given in brackets. The chemical composition assigned to each is that of a chemically-pure specimen. The substances are arranged alphabetically, and those marked with an asterisk are artificial, while those with a double asterisk have undergone preparation. These latter are elements, and, with the exception of tellurium, are not found in an elemental state in nature :—

Argentite (Silver glance) ...	Ag_2S.
Blende (Sphalerite)	ZnS.
Bornite (Erubescite)	$3Cu_2S_3.Fe_2S_3$.
*Carbon Silicide	CSi.
*Carborundum	SiC.
Cassiterite (Tinstone) ...	SnO_2.
Cerrusite	$PbCO_3$.
Chalcocite (Copper glance) ...	Cu_2S.
Copper pyrites (Chalcopyrite)	$Cu_2S_2.FeS_2$.
Corundum	Al_2O_3.
Domeykite	Cu_2As.
Galena	PbS.
Graphite (Plumbago) ...	C.
Hessite	Ag_2Te.
Hæmatite	Fe_2O_3.
Iron Pyrites (Mundic) ...	FeS_2.
Malachite	$CuCO_2.CuH_2O_2$.
Molybdenite	MoS_2.
Niccolite (Kupfernickel) ...	$NiAs$.
Octahedrite (Anatase) ...	TiO_2.
Pyrrhotine (Magnetic pyrites)	FeS.
Siderite (Chalybite)	$FeCO_3$.
**Silicon	Si.
Stromeyerite	$Ag_2S.Cu_2S$.
**Tellurium	Te.
Zincite	ZnO.
**Zirconium	Zr.

The reader will be quite well aware that there are a score or more of crystals to be obtained from dealers and which are not included in the above list. Many of these crystals are nothing more than galena. It is quite possible they may be selected and have been tested for sensitiveness, but that is all. There may be some specimens which have undergone some form of treatment, but so far the writer has handled but one specimen only which is entirely artificial and prepared definitely for wireless work.

Crystal Combinations.—Crystals may be divided into two classes :—(1) Those which must be in contact with another crystal, the two forming what is often called a " perikon " detector ; (2) those which require a metal contact. Chief among those of the first group are the following :—

Zincite with tellurium, copper pyrites, chalcocite, or bornite.
Galena with tellurium or graphite.

In the second group the following are prominent :—

Carborundum with steel.
Galena with silver, brass, copper, or gold.
Silicon with gold or steel.
Iron pyrites with gold.
Molybdenite with silver.

Notes on Crystals.—A few remarks on these combinations may be useful. In the perikon combinations it is most essential that the pressure at the point of contact be most carefully adjusted. Zincite, tellurium, and galena are very brittle and friable. Copper pyrites and bornite are relatively hard, and will soon grind away the fine points of the softer crystals. It is also important that the points making contact are bounded by natural angles. Any filing or grinding to shape is useless. When points need renewing it is best to chip away the old faces with a needle point. Carborundum—a product of the electric furnace—sometimes offers difficulties to the amateur who uses it for the first time. It may be obtained in pieces of varying structure and colour. The very hardest varieties, which show well-defined crystals, and have usually a brilliant display of iridescent colours, is worthless for detectors. The two best kinds are the steel-grey, glassy variety, and the somewhat fibrous, greenish-grey variety. The former is slightly more sensitive than the latter, but not so stable in action. The steel contact is best in the form of a flat strip—a piece of clock-spring being excellent. The pressure may amount to as much as 2 or 3 lbs. It is necessary for best results to apply a small potential across the detector. The rectifying action of crystals is often improved in this way, though usually the improvement is so small as to make the employment of the extra apparatus hardly worth while. Carborundum will function without applied potential, but its addition makes a most marked improvement. Fig. 1 is the characteristic curve of carborundum showing how its resistance varies as the applied potential rises. If the potential is adjusted so that the crystal functions just at the bend in the curve it will be in its most sensitive condition. Fig. 2 shows a simple potentiometer for this purpose. It consists of a small slab of ebonite wound with about 20 yards of No. 40 Eureka wire (enamelled or silk covered). A tapping is taken from the centre of the winding, and a spring contact sweeps across the top of the winding. A battery of three small dry cells (a flashlamp refill) is joined across the winding and forms the source of potential. Fig. 3 shows the connections of battery, potentiometer and detector.

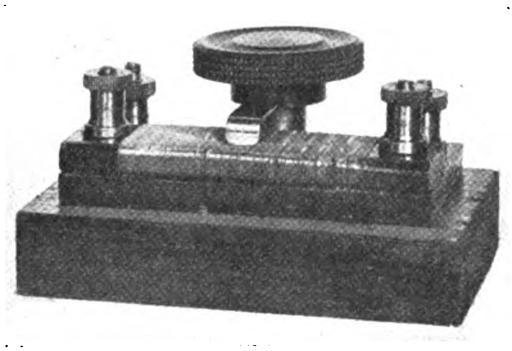


Fig. 2.—A potentiometer for use with carborundum.

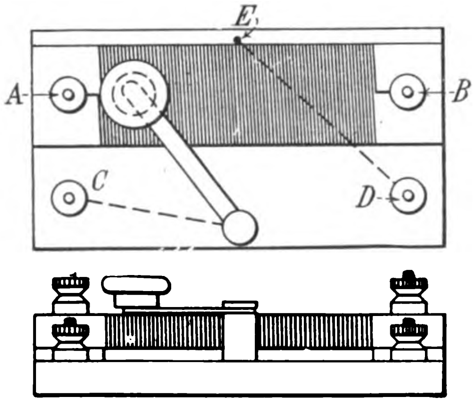


Fig. 3.—Connections of the potentiometer

A and B — To Battery. C — To Inductance.
D — To Detector. E — Central Tapping.

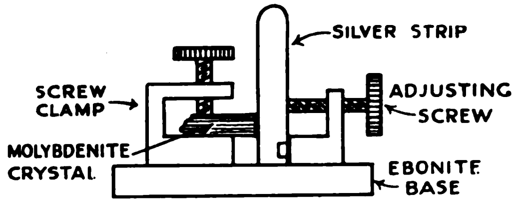


Fig. 4.—Design for a molybdenite detector.

The silver contact for molybdenite is also best in the form of a flat strip bent in the shape of a U spring. Molybdenite is a substance much resembling graphite. It is, however, brighter in colour, and makes a greenish-grey streak when rubbed on paper. It is lamellar in structure, and in use should be cut at right-angles across the laminæ, the surface being made smooth with very fine emery paper. Fig. 4 gives a suggestion for

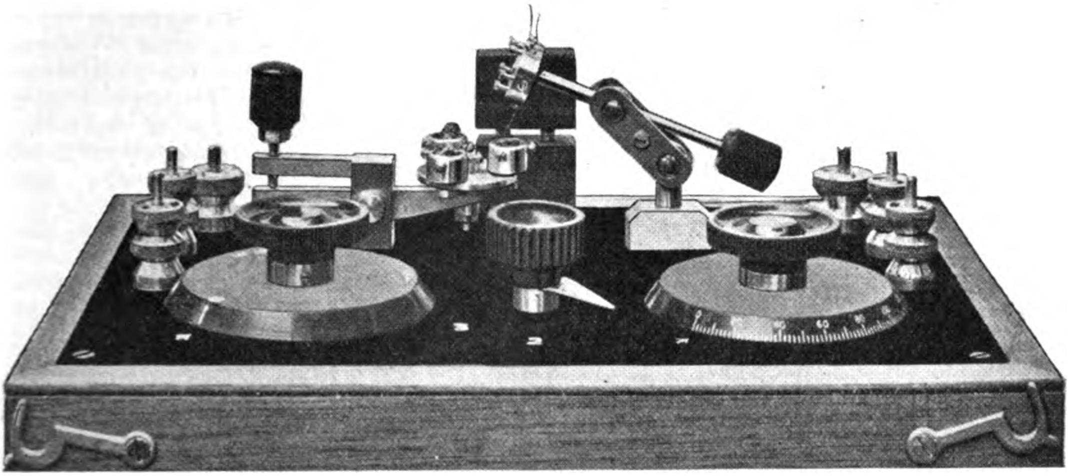


Fig. 5.—View of the top of the crystal testing set, showing the universal movement of the detector mountings.

a suitable arrangement. All other metal points are best in the form of wire—about 30 gauge being suitable. The artificial crystal mentioned before works very well with gold, silver or brass, but better as a perikon with bornite or copper glance, the latter being the better of the two.

Mounting Crystals.—Some diversity of opinion exists as to the best method of mounting crystals. The original method was to set the crystal in a brass cup, using Wood's metal as a cement. It is now common practice to use a brass cup fitted with one or more set-screws. Some affirm that the heat of the melted Wood's metal has an injurious effect on the crystal. The writer does not altogether agree with this except, perhaps, in the case of molybdenite. Wood's metal is an alloy of lead, tin, bismuth, and cadmium, and, if of correct composition, melts at 66° C. Another alloy—Lipowitz's—contains the same constituents in slightly different proportion, and melts at 60° C. These temperatures are well below that of boiling water, and will not damage a crystal. Many samples of fusible metals sold for the purpose are not Wood's metal, and require a much higher temperature to make them fluid. In these cases there is some risk in spoiling a delicate crystal. There would seem to be just as much risk of spoiling a brittle crystal in using set-screws, because these must be screwed up really tight in order to secure good contact. For the experimenter who wishes to change his crystals frequently the screwed cup has its advantages, perhaps, but for permanent use there is much in favour of setting the crystal in Wood's metal—only it must be the right grade.

The Detector.—For really good results the mechanical side of the detector requires some care in design. While freedom of movement must be provided to the metal contact, for instance, there must be no slackness or shakiness. As before mentioned, the pressure at the point of contact is extremely important, and this seems in a great many detectors difficult to arrange with certainty. Electrical continuity in the moving metal parts is, of course, vital, and just as vital is the question of insulation in the mounting. Dust is a most insidious enemy, and it is a sign of advancement to see types of protected detectors now appearing in dealers' lists and windows. Some of these protected types would be better if the glass or celluloid covers were a little larger; movement of the metal point seems a little cramped and restricted.

Some Suggestions.—Some small observations will now be given from the writer's experience. The question is often asked, "Which is really the best detector?" This is not quite easy to answer. Personally, the writer believes that for all-round efficiency, simplicity in adjustment, and constancy in action under all conditions there is nothing to beat the carborundum-steel with its battery and potentiometer. When a crystal

is used in conjunction with a valve for either high- or low-frequency amplification, carborundum is preferable to any other crystal. It also stands up well against atmospheric disturbances, and it is the only crystal that will survive the proximity of high-tension discharges such as are used in spark transmission.

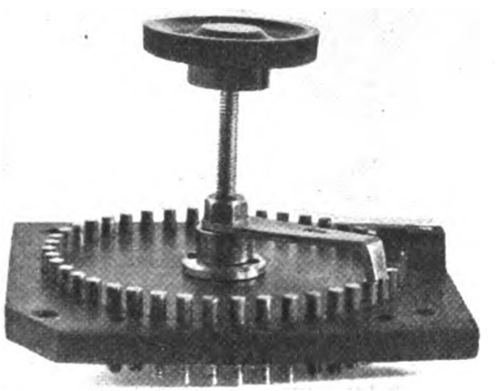


Fig. 6.—The inductance selector switch, mounted beneath the panel.

Beyond the metal points mentioned earlier, phosphor-bronze or german silver will sometimes give good results with certain crystals. Certain combinations, such as silicon and gold, give very good results when L.R. 'phones are used. This is, no doubt, because such a combination has a much lower resistance than others. It will be found, too, that while it is better to use two or more pairs of H.R. 'phones in parallel, L.R. 'phones are best joined in series. The writer has noticed on more than one occasion that, using silicon on 2LO broadcasting, distant spark signals are very faint; yet, changing over to galena, these distant signals become much stronger, while 2LO is weaker. Finally, in the writer's opinion, many amateurs use crystals far too large in size. Given a good specimen, there is not the slightest advantage in using a large piece.

Testing Crystals.—To test out a crystal thoroughly one must work on a definite system, and the matter requires some little patience. The writer has done a fair amount of crystal testing for commercial purposes. The specimens come in small bags, numbered, but generally un-named, and are usually in pieces about the size of a cherry stone and larger. Broadcast transmission is generally used for test purposes in order that purity of tone may be judged, and reception is taken on both Brown's "A" type 'phones, and also the usual diaphragm pattern. Pieces are first taken from each sample and mounted up in screwed cups. The plan generally adopted is first to test each specimen with various metal points, assigning so many marks of a possible ten to each test. If required the specimens are tested with others in a perikon combination. Having found the best combination, this is used to find the total area of sensitivity and also the uniformity of sensitivity over the whole area, assigning marks as before. All this takes time, but it is the only way in which a satisfactory report can be rendered. The question of the effective life of a crystal can only be settled by periodical tests over a length of time.

A Tuner for Crystal Testing.—In order that the procedure mentioned above may be carried out expeditiously and as thoroughly as possible, the writer has designed and constructed a receiver which embodies several features not usually found in a crystal set. Fig. 5 shows the general appearance of the set. On the left is the selector switch from the tapped inductance. This is wound on a paxolin tube 3½ ins. diameter. The winding is 130 turns of No. 28 s.s.c. wire. Tappings

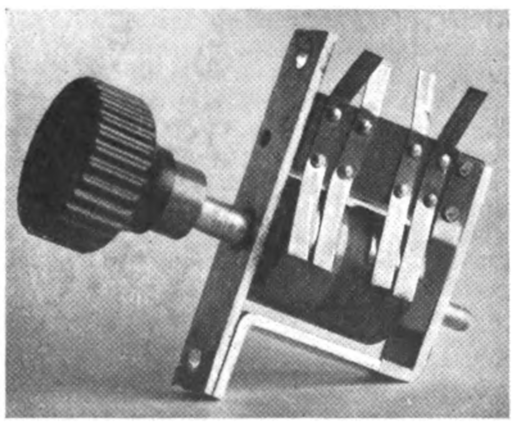


Fig. 7.—Illustrating the construction of the dead-end switch.

are taken from the tenth turn and then from every three. The winding is divided into three sections, which are isolated by a dead-end switch, the control knob of which is seen in the centre. The first section finishes at the eighteenth stud of the switch, and the second at the thirty-second stud.

This gives ranges of, approximately, 500 metres, 900 metres and 1,200 metres. If longer ranges are required a loading coil can be plugged into the holder at the back of the panel. This holder is of the standard pattern to take the plugs usually fitted to lattice coils, and, normally, is short-circuited by a plug. On the right is a variable condenser with total capacity of 0·0005 mfd. Between the three control knobs and the loading coil socket is the detector. On the right is a capstan head which will carry five wire contacts. It is mounted in a double ball-and-socket fitting so that movement in all directions is provided and any wire contact can be selected at will. The fitting on the left carries three removable crystal cups mounted capstan fashion, and the screw on the extreme left provides a micrometer rise and fall to the crystal cups, the arm on which they are mounted being a first order lever. Good contact and smoothness in action is secured by a phosphor-bronze spring thrusting the arm against the adjusting screw. In this fitting the difficulty of providing that delicacy of pressure which is so essential has been overcome, and the detector proves entirely satisfactory in action. The selector switch is mounted below the panel so that it is protected from dust, Fig. 6 giving a close-up view of it. The dead-end switch shown in Fig. 7 is simply a short cylinder of ebonite carrying two brass plates which make contact with two pairs of bronze fingers.

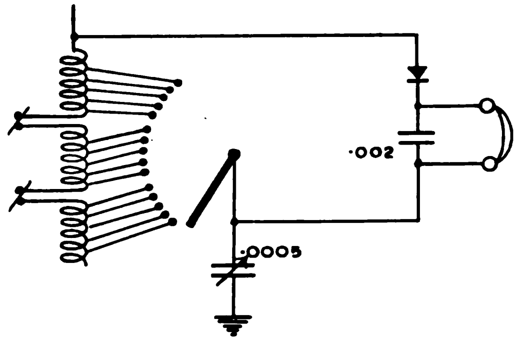


Fig. 8.—The circuit employed on the testing set.

Altogether, the set has well repaid the time taken in its construction, as not only is really good reception obtained with accurate tuning, but crystal testing is greatly facilitated and can be done with certainty. Fig. 8 is the wiring diagram of the set. It might be mentioned, perhaps, in closing, that when crystals of the perikon group are being tested a separate detector of special design is used.

An Ultra-Selective Receiver.

By "2SH."

Below will be found some details of a new circuit embodying several new features Readers who test out the scheme will, no doubt, be surprised at the results obtainable.

NOW things are returning to normal after the upheaval caused by the advent of broadcasting in the experimental world, many amateurs are finding the problem of selectivity a very pressing one. The ordinary single-valve reaction set, when used at a distance of less than 5 or 6 miles from a broadcasting station, will not cut out that station entirely on any wavelength. This can be greatly improved by loose coupling the aerial circuit, but such circuits are not easy to handle while getting good signals in searching. In the U.S.A. where anyone can get a transmitting licence for 1 kw. this problem has been of importance for many years. If you have a neighbour with 1 kw. of I.C.W. on 200 metres you have rather a thin time near his wave. The solution over the other side has been the "three-circuit regenerator," which consists of a loose-coupled set with a tuned plate circuit. The primary coil is the fixed winding of a vario-coupler, and the secondary is the vario-coupler rotor in series with a variometer. The plate is tuned with another variometer (see Fig. 1). The primary is

tuned by tappings and sometimes a series aerial condenser. The secondary has no condenser. This type of set is very selective, but it needs, as someone once said, "three hands and a foot" to tune it properly. Every change in the secondary circuit necessitates a critical readjustment of the plate variometer. In consequence of this difficulty many American experimenters have been attempting to find a good selective

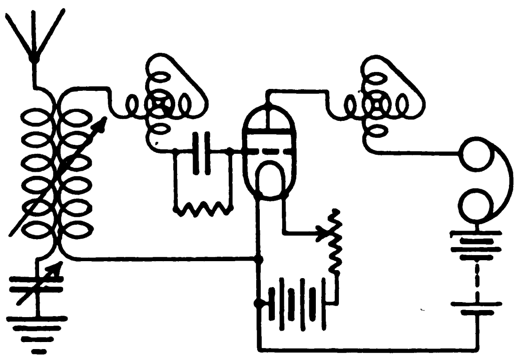


Fig. 1.—An ordinary regenerative circuit in which the selectivity is increased by tuning the closed circuit and the anode circuit with variometers.

single-valve circuit with few adjustments. A year or so ago the Reinartz tuner was brought out, and this circuit (Fig. 2) certainly gives great selectivity with simple adjustment, but, unfortunately, the signal strength is much reduced. It will be seen that this circuit uses a small untuned aerial coil and "shunt" reaction coil. The secondary coil is excited by shock.

However, within the last few months a new circuit has been evolved by Mr. L. M. Cockaday, which he calls the four-circuit tuner. This sounds worse than before, but is not!

In an ordinary regenerative circuit by increasing reaction coupling we decrease the positive resistance of the circuit by increasing the negative resistance, until at length the latter exceeds the former and the set begins to oscillate. In this new circuit we use the reverse process. An easily oscillating valve circuit is used, and the positive resistance is increased until the oscillations are manageable. In this set the aerial coupling is as loose as possible for good strength of signals, and the reaction control varies very little with quite a large change of wave-length. Owing to the circuit arrangement the aerial need not be accurately tuned, so that our only controls are the grid tuning condenser and reaction. Instead of the usual circuit we use the De Forest Ultraudion circuit for our oscillating valve. Usually this circuit cannot be easily stopped oscillating and is not manageable. Here we arrange it to oscillate as it wishes, and we subtract energy from the grid circuit until the desired state is reached. This is done by the "fourth circuit," which is a small tuned trap coupled to the grid coil. Note that this circuit is not tuned to the working wave, but usually well below it. This distinguishes between this circuit and a freak type of multiple tuner. The circuit is shown in full in Fig. 3. The aerial circuit is made up of the two coils A and B. A is tapped every few turns. B consists of one turn of thick wire. C, the trap, consists of a small coil with ·0005 condenser, wound close to the tuning coil D on the same former. B is coupled to the end of C farthest from D. This coupling can be adjusted on test, and when the best value is found it may be left. It will be found that no appreciable strength is gained by tuning the aerial accurately. As for correct sizes for coils, all should be wound with at least 20 D.S.C. wire. A may

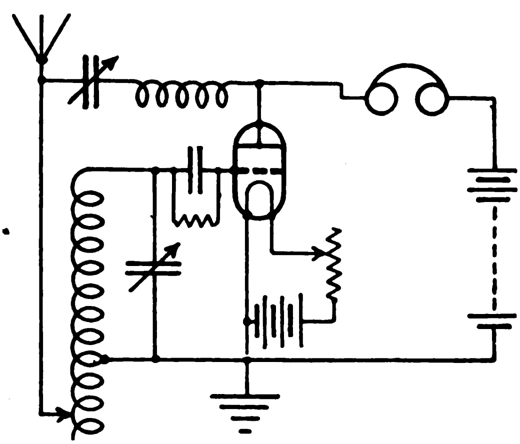


Fig. 2.—In one type of the Reinartz circuit, the aerial coil is untuned, and the reaction coil is connected in shunt.

be 5 ins. diameter, turns spaced $\frac{1}{8}$ in., tapped every five for thirty turns. B should be about 14 S.W.G. C and D should be on a 4-in. former, and of 30 and 50 turns respectively, close wound, with $\frac{1}{4}$ in. between coils. D should be tapped at 25 turns. The method of operation is as follows :—

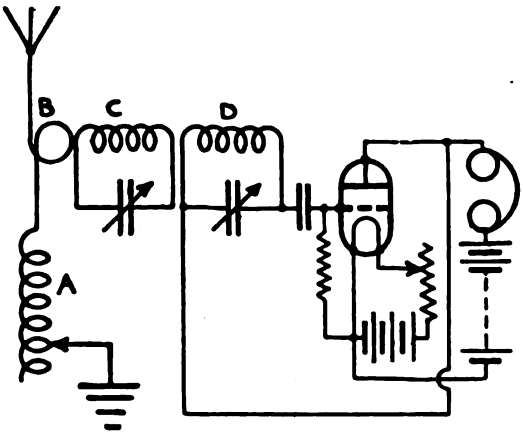


Fig. 3.—The aerial is coupled by a single turn to the trap circuit, which is not tuned to the desired frequency.

Put the condenser across C to zero, and adjust the valve until it oscillates vigorously. Then increase condenser C and so stop oscillations. Set A to approximately the correct value, and search with condenser D. C will be found to need little adjustment. A few minutes practice will show the simplicity and extraordinary selectivity. Unfortunately, it is not legal to use this set for broadcasting, but the radiation is extremely small owing to the loose coupling. It would be found possible, however, to receive any station at will, which is quite impossible with an ordinary set.

I hope these notes will interest some sufficiently to test out this circuit, for it is well worth while. It will be found that all signs of broadcasting will be cut out on slightly shorter waves, which is not usual with one-valve sets. If desired the filaments may be earthed. This will help to eliminate any body capacity effects.

The Trend of Invention.

We summarise below the more important wireless inventions which have been disclosed during the month, special reference being made of those of immediate interest to the experimenter.

Tuning Devices.

Fig. 1 illustrates a rather ingenious method of simultaneously decreasing the capacity and inductance of a tuned circuit. A moveable plate 9 acts partly as a variable condenser in conjunction with a fixed plate 5, and partly as a means for varying the effective inductance of the tuning coil 3. The disc 9 acts as a closed circuit variably coupled to the coil 3, so that as it is moved towards the coil the mutual inductance between the two circuits decreases the effective self-inductance of the coil 3; at the same time the capacity between 9 and 5 is decreased. (A. H. S. MacCallum, Brit. Pat. 202,115.)

Another tuning device recently patented, primarily consists of a condenser having vernier and main elements mounted on separate but coaxial shafts with an inter-locking device which permits the vernier section to act alone over a certain range, after which the main section is brought into play. The condenser can therefore be used over a wide range of tuning. (H. Saville and C. H. Thornton, Brit. Pat. 201,816.)

Smoothing Device.

Fig. 2 is rather a novel departure in smoothing circuits; it is intended to fatten out pulsating D.C. such as may be obtained from a rectifier. The pulsating input is applied at A and is fed into an electrolytic cell or a number of cells in series at F which become polarised. From F the current passes to the output B through a loose contact device C, whose resistance varies with the pressure on the diaphragm D. Across the cell F is an electro-magnet E, fluctuations in which cause a varying pull on the diaphragm D, thereby tending to neutralise fluctuations in current passed to the output B.

Signalling by High-Frequency Mechanical Vibrations in Material Media.

Apparatus for transmitting sound waves of audible or super-audible frequency through water or similar media is described in British Patent 200,709. Oscillations generated by an arc, alternator or commutator are applied to a special electrostatic condenser device which may be submerged in the water surrounding a ship or other vessel. Owing to the varying electrostatic attraction between the plates of the device they vibrate in response to the applied alternations, thus imparting a vibratory disturbance to the water, which is propagated to a distance, and may be detected by some suitable submersible responsive device. Instead of immersing the electrostatic vibrator in the water outside the vessel a vibrator may be installed inside in such a manner as to impart its vibrations to the wall of the vessel which in turn sets up the requisite compression waves in the water. It is stated that the device

works well with high frequencies and lends itself to telephony. Its most important use is in submarine communication.

Atmospheric Elimination.

In designing circuits to discriminate between atmospherics and signals, we have taken into account the fact that atmospherics are aperiodic impulses which kick any tuned circuit into oscillations of its own natural frequency; hence the difficulty of eliminating the effects of atmospherics with ordinary selective circuits. A new system has recently been patented by H. J. Round (Brit. Pat. 200,857). Coupled to an aerial, preferably one having the best directional properties, are two tuned circuits in cascade; these circuits are so adjusted that their respective resonance curves are as near together as possible without overlapping, one being exactly tuned to the signals to be received. At the end of these circuits are connected two detectors, so balanced that only the difference between the currents set up in the two circuits affects the indicating device. Thus an atmospheric impulses both tuned circuits equally into their own free periods, and the effects therefore cancel in the indicating device. The tuned signal, however, materially affects only one circuit, and is recorded. What is actually recorded by, say, a syphon recorder is the difference between the signal and atmospheric amplitudes. This difference may be large, small, positive or negative according to the phase relation between signal and atmospheric, but in any case nothing is recorded by the atmospherics themselves in the absence of a signal.

Sealing Leading-in Wires for Heavy Currents into Glass.

One of the chief difficulties in constructing lamps, valves or enclosed arcs to handle large powers is that of producing a satisfactory metal-to-glass seal. Thick leading-in wires, even if made of platinum or other metal with the same co-efficient as glass, present serious difficulties when it is attempted to make a robust and permanently gas-tight seal. The Dutch firm of Philips, which holds a large number of lamp and valve patents, has developed a seal in which the lead-in is made by means of a chrome-iron disc, the circumference only of which is fused into the glass. (Chrome-iron can be made to have the same co-efficient of expansion as glass.) The heavy current leads are attached to the centre of the chrome-iron disc on either side. (Brit. Pat. 198,322.)

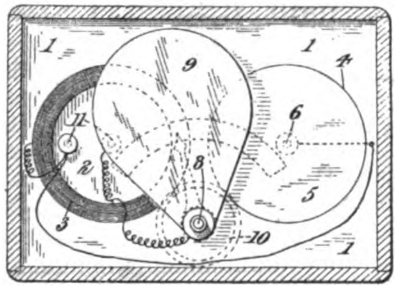


Fig. 1.

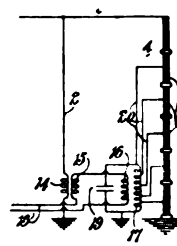


Fig. 5.

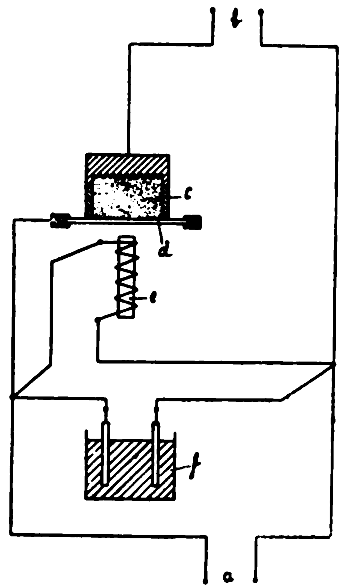


Fig. 2.

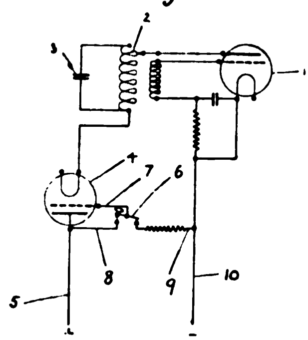


Fig. 3.

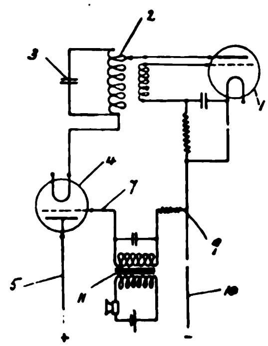


Fig. 4.

Fig. 1.—A method of simultaneously varying inductance and capacity. **Fig. 2.**—An arrangement to smooth pulsating D.C. **Fig. 3-4.**—A system of keying or modulating the output of a valve oscillator. **Fig. 5.**—The mast is divided into a number of insulated sections, supplied with graded potentials.

A System of Modulation.

Numerous patents have been filed for modulating the output of valve transmitters for telephony and keying them for Morse. Figs. 3 and 4 illustrate a scheme recently patented by N. F. S. Hecht (Brit. Pat. 201,276). A control valve is placed in series with the positive H.T. lead as shown. When the key (Fig. 3) is up, the grid of the control valve 4 is connected to the negative H.T. lead and is thereby maintained at a sufficiently great negative potantial to cut the current through the

valve down to a low value. When the key is down the grid is connected straight to the plate, and thus brought to full positive H.T. potential under which circumstance the control valve passes its full saturation current. The modulation scheme in Fig. 3 should give good results, but it is not quite clear where the novelty lies, other than the use of the control resistance 9.

Aerial Improvements.

The Telefunken Co. describe in Brit. Pat. 180,673 a system in which the aerial is broken up into a number of elements, each fed from the transmitter, so arranged that the energy is utilised equally. The system is comparable with the Alexanderson multiple-tuned aerial.

E. Y. Robinson gives details in Brit. Pat. 201,264 of a system of breaking up the aerial mast into insulated sections, a tapped inductance supplying graded potentials to the various sections The disturbing effects of the metal mast are hus eliminated, as shown in Fig. 5.

Microphone Singing.

The singing effect between a microphone and telephone receiver is well-known, and the Telefunken Co. have devised a method of eliminating the effect. The microphone is connected in a form of bridge circuit, of which one arm is equivalent to the line in use and the whole is so balanced that currents from the transmitter do not affect the local receiver. Full details will be found in Brit. Pat. 178,860.

Recent Wireless Publications.

Figures after the title of each publication indicate Volume and Number of Publication containing the article. Where only one number is given, this indicates the serial number of the publication.

ABBREVIATIONS OF TITLES OF JOURNALS USED IN THE BIBLIOGRAPHY.

Amer. Acad.—American Academy of Arts and Sciences.
Am.I.E.E. J.—Journal of American Institute of Electrical Engineers.
Ann. d. Physik—Annalen der Physik.
Boll. Radiotel.—Bolletino Radiotelegraphico.
Elec. J.—Electric Journal.
El. Rev.—Electrical Review.
El. Times—Electrical Times.
El. World—Electrical World.
Electn.—Electrician.
Frank. Inst. J.—Journal of the Franklin Institute.
Gen. El. Rev.—General Electric Review.
Inst. El. Eng. J.—Journal of the Institute of Electrical Engineers.
Inst. Rad. Eng. Proc.—Proceedings of the Institute of Radio Engineers.
Jahrb. d. drahtl. Tel.—Jahrbuch der drahtlosen Teleg. etc.
Mod. W.—Modern Wireless.
Nature—Nature.
Onde El.—L'Onde Electrique.
Phil. Mag.—Philosophical Magazine.
Phil. Trans.—Philosophical Transactions.
Phys. Rev.—Physical Review.
Phys. Soc. J.—Journal of Physical Society of London.
Q.S.T.—Q.S.T.
R. Elec.—Radio Electricité.
Roy. Soc. Proc.—Proceedings of the Royal Society.
Sci. Abs.—Science Abstracts.
T.S.F.—Telegraphie sans fils, Revue Mensuelle.
Teleg. without Wires, Russia—Telegraphy without Wires, Nijni Novgorod.
W. Age—Wireless Age.
W. Trader—Wireless Trader.
W. World—Wireless World and Radio Review.

1.—TRANSMISSION.

DIRECTIVE RADIO TRANSMISSION ON A WAVE-LENGTH OF 10 METRES.—S. R. Winters (*W. Age*, 10, 11).

VOLTAGE RAISER FOR VALVE TRANSMITTERS.—Marcus G. Scroggie B.Sc. (*W. World*, 290).

THE TRANSMISSION OF PICTURES BY WIRELESS.—J. H. T. Roberts, D.Sc., F.Inst.P. (*Mod. W.*, 1, 8).

A HIGH-POWER WIRELESS VALVE CAPABLE OF BEING DISMANTLED.—(*El. Rev.*, 93, 2387).

RADIO BROADCASTING STATION, W.G.Y. (U.S.A.).—W. R. G. Baker (*Gen. El. Rev.*, 36, April, 1923).

A 30-KILOWATT 15,000-VOLT RECTIFIER FOR THE UNITED STATES NAVY.—A. Schmidt, Jr. (*Gen. El. Rev.*, No. 26, May, 1923).

BROADCASTING STATION AT SCHENECTADY, NEW YORK.—W. R. G. Baker (*Inst. Rad. Eng. Proc.*, 11, 4).

VACUUM TUBES AS POWER OSCILLATORS, PART 2.—D. C. Prince (*Inst. Rad. Eng. Proc.*, 11, 4).

IL CENTRO RADIOTELEGRAFICO DI COLTANO (*Boll. Radiotel.* 2, 22).

THE NODAL POINT EXPLAINED.—H. F. Mason. (*Q.S.T.*, 7, 2).

THE BEST DIMENSIONS FOR AMATEUR ANTENNAS.—Ross Gunn (*Q.S.T.*, 7, 2).

2.—RECEPTION.

STATIC ELIMINATION PHANTASIES.—Carl Dreher (*W. Age*, 10, 11).

AN ARMSTRONG SUPER RECEIVER.—5HZ (*W. World*, 209).

DISTORTION IN VALVE RECEIVING CIRCUITS. Part 1.—S. O. Pearson, B.Sc. (*W. World*, 211).

HINTS ON BETTER RECEPTION.—W. James (*W. World*, 211).

MY NEW CIRCUIT.—E. T. Flewelling (*Mod. W.*, 1, 8).

RADIO ATMOSPHERIC ELIMINATION. THE MARREC SELECTIVE RECEIVING APPARATUS (*El. Rev.*, 93, 2388).

Long Distance Radio Reception in India.—P. J. Edmunds, B.A. (*Electn.*, 2361).

Super-Regeneration.—P. David (*Onde El.*, No. 2, April, 1923).

On Super-Regeneration.—E. O. Hulburt (*Inst. Rad. Eng. Proc.*, 11, 4).

Loop Uni-Directional Receiving Circuits for the Determination of the Direction of Atmospheric Disturbances.—L. W. Austin (*Inst. Rad. Eng. Proc.*, 11, 4).

Theorie der Beverage-Antenne, 2.—H. Busch (*Jahrb. d. drahtl. Tel.*, 21, 6).

Experimentaluntersuchung über die Verglimmlichverstärkerröhre.—E. Marx (*Ann. d. Physik*, 70, 4).

3.—MEASUREMENT AND CALIBRATION.

Practical Tables for Inductance and Coil Calculations (*W. Age*, 10, 11).

Note on the Calibration of a Heterodyne Wavemeter.—E. Mallet, H. Andrewes, and E. T. A. Rapson (*Electn.*, 2363).

Receiving Measurements and Atmospheric Disturbances at the United States Naval Radio Research Laboratory, Bureau of Standards, Washington, March and April, 1923.—L. W. Austin (*Inst. Rad. Eng. Proc.*, 11, 4).

Standards of Capacity particularly for Radio Frequency Currents.—J. B. Dempster and E. O. Hulbert (*Inst. Rad. Eng. Proc.*, 11, 4).

Anleitung zum Selbstherstellen eines tragbaren Wellenmessers für kurze Wellenlängen für Amateure.—Bureau of Standards (H. Eales) (*Jahrb. d. drahtl. Tel.*, 21, 6).

Messung der Kapazität dünndrähtiger Spulen von hoher Windungszahl und die Abhängigkeit des Factors der Thomsonschen Gleichung von der Grösse der Zusatzkapazität.—Erich Marx and August Karolus (*Physikal. Zeitschr.*, 24, 3).

Experimentelle Untersuchungen unter die Beugen ungedämpfter elektrischer Wellen an dielektrischen Zylinder und über die Eigenschwingungen dielektrischer Zylinder.—C. Schaefer and J. Merzkirch (*Zeitschr. für Physik*, 13, 3).

4.—THEORY AND CALCULATIONS.

Etude des Antennes en Nappe.—R. Villem (*R. Elec.*, 4, 11).

Longeur d'Onde Optimum.—Léon Bouthillon (*R. Elec.*, 4, 11).

Propagation of Electromagnetic Waves Over the Surface of the Earth.—Léon Bouthillon (*Journ. Télegraph*, 47).

Berechnung der Kopplungskoeffizienten für einige besonderen Fälle der gegenseitigen Induktion.—D. Wicker (*Jahrb. d. drahtl. Tel.*, 21, 6).

Vektoranalysis in ihren Grundzügen und wichtigsten physikalischen Anwendungen.—A. Haas (reviewed in *Jahrb. d. drahtl. Tel.*, 21, 6).

Der Aufbau der Atome aus Uratomen.—L. Zehnder (reviewed in *Jahrb. d. drahtl. Tel.*, 21, 6).

Einführung in die Ionen- und Elektronenlehre der Gase.—H. Greinacher (reviewed in *Jahrb. d. drahtl. Tel.*, 21, 6).

Mathematische Einführung in die Gravitationstheorie Einsteins nebst einer exakten Darstellung ihrer wichtigsten Ergebnisse.—H. Bauer (reviewed in *Jahrb. d. drahtl. Tel.*, 21, 6).

Valve Performance.—P. K. Turner (*W. Trader*).

5.—GENERAL.

Notes on Vacuum Tubes.—M. L. Snyder (*W. Age*, 10, 11).

The New Signal Code.—Louis Cohen, Ph.D. (*W. World*, 209).

Some Experiments Illustrating the Electrical Properties of Neon Lamps.—Demonstration by Philip R. Coursey before the R.S.G.B. (*W. World*, 210).

Duplex Radiotelephony on Continental Railways.—Nicholas Langer (*W. World*, 211).

A Low-Voltage Cathode Ray Oscillograph.—N. V. Kipping (*W. World*, 212).

La Radioélectricité et la Télépathie.—Henri Aubert (*R. Elec.*, 4, 10).

L'Invention de la T.S.F.—J. Guinchant (*R. Elec.*, 4, 10).

A Propos de la Radiogoniometrie (*R. Elec.*, 4, 10).

A Propos de Colloides.—Joseph Roussel (*R. Elec.*, 4, 11).

Les Tubes Thermoioniques à Vapeur Métallique.—Michel Adam (*R. Elec.*, 4, 11).

The Crystals Used in Wireless.—E. H. Chapman, M.A., D.Sc. (*Mod. W.*, 1, 8).

Commercial Wireless Telegraphy in South America (*El. Rev.*, 93, 2388).

Interference.—Robert H. Marriott (*Inst. Rad. Eng. Proc.*, 11, 4).

Digest of U.S. Patents Relating to Radio Telegraphy and Telephony Issued April 24, 1923—June 19, 1923.—John B. Brady (*Inst. Rad. Eng. Proc.*, 11, 4).

Atlas der Funktelegraphie und Seekabel im Weltverkehr.—H. Behner (reviewed in *Jahrb. d. drahtl. Tel.*, 21, 6).

Uber Verstärkung der photoelektrischen und Ionisationströmer mittels der Elektronenröhre.—G. de Prel (*Ann. d. Physik*, 70, 3).

The Motion of Electrons in Gases under Crossed Electric and Magnetic Fields.—Rabindra N. Chaudhuri, M.Sc., Ph.D. (*Phil. Mag.*, 46, 273).

Electrical Discharges in Geissler Tubes with Hot Cathodes.—W. H. McCurdy, M.A. (*Phil. Mag.*, 46, 273).

The Motion of Electrons in Hydrogen under the Action of Crossed Electric and Magnetic Fields.—R. N. Chaudhuri, M.Sc., Ph.D. (*Phil. Mag.*, 46, 273).

The Application of a Revolving Magnetic Drum to Electric Relays, Siphon Recorders and Radio Transmitting Keys.—N. W. McLachlan (*Inst. El. Eng. J.*, 321).

The Design of Inductances for High Frequency Circuits.—Prof. C. L. Fortescue (*Inst. El. Eng. J.*, 321).

The Best Dimensions for Amateur Antennas.—Ross Gunn (*Q.S.T.*, 7, 2).

Experimental Wireless

A JOURNAL OF RADIO RESEARCH AND PROGRESS

Vol. I, No. 2. NOVEMBER, 1923. 1s. NET.

Experimental Topics.

Our Progress.

WE do not propose to take up very much space this month in talking about ourselves, but so many complimentary letters have reached us in regard to our first issue that it would be ungrateful on our part not to pen these few lines of acknowledgment and sincere thanks. In addition to compliments we have had suggestions and helpful criticisms which will be directly useful to us in shaping our course; for these we also tender our appreciation. It is quite obvious that EXPERIMENTAL WIRELESS has already made many good friends, and we shall hope to continue to deserve their friendship. Last month we asked our readers to suspend their final judgment on our programme till they had seen several issues. In the present number we get a little more into our real stride, and we are quite sure that as the months go on it will be found that our scheme of an "all-experimental" paper is not only practical, but is of real service to the wireless community in general, and that it possesses an individuality and an interest of its own.

The] Broadcasting Report.

Everybody seems agreed that the Report of the Broadcasting Committee was excellent; but there is not quite the same unanimity of feeling in regard to the decisions of the Postmaster-General. Bound as he was by an agreement with the Broadcasting Company, he could at best only effect a compromise, and apart from a few minor points we think he has done wisely and well. The way has been cleared for the constructor to get busy with his tools, the olive branch has been held out to the "pirates," and the ordinary listener-in is cheered by the prospect of a reduction in prices of complete sets. No one suggests that the P.M.G. has provided a perfect solution to the licence problem, but his proposals will help the wireless industry to get busy again, and in the fulness of time a simpler and more generally acceptable licensing scheme may receive the official blessing.

Freedom for Experimenters.

In the first announcement of the Postmaster-General's decision it was stated that experimental licencees would be required to make a declaration that they would not use their apparatus for listening-in to broadcasting other than for experimental purposes. The futility of such a requisition is obvious, and we understand now that by paying an additional five shillings experimenters may enjoy the full service of the broadcasting stations with a clear conscience. Many experimenters will, no doubt, be quite willing to make this small supplementary contribution to the funds of the B.B.C. in return for the service provided, but there will be others who have no interest in broadcasting as an entertainment. Our own view is that the issue of the experimental licence

should be jealously guarded, but once the experimenter has satisfied the authorities as to his qualifications and intentions, the cost of the licence should be made a minimum and the freedom of action a maximum. Amateur experimenters of the right type are exceedingly valuable auxiliaries both to the science and to the industry; they carry on their research for the sheer love of the work, and probably much of the technical progress achieved during the next decade will be due to their general co-operation if not to their individual effort. The experimenter will probably contribute to the improvement of broadcasting in other and, possibly, more important respects than his mere payments to the B.B.C. funds.

The Wireless Exhibition.

Every experimenter who can possibly get within reach of Shepherds Bush will want to attend the all-British Wireless Exhibition to be held there from November 8 to the 21st. The Exhibition is being organised by Messrs. Bertram Day & Co., Ltd., in conjunction with the National Association of Radio Manufacturers, and there is no doubt that there will be a very interesting and representative show of all that is latest and best in British wireless equipment. EXPERIMENTAL WIRELESS will be represented there at Stand No. 22, and we shall be pleased if as many of our readers as possible will pay us a call.

The Transmitting Tangle.

We expressed last month our views on the need for greater co-operation among amateur experimenters. We now return to the subject because the cleavage in the transmitting world has become more clearly defined, and the difference of opinion more acute, a state of affairs which, in the true interests of amateur transmitting, is much to be regretted. From reports which appear elsewhere in this issue it will be observed that the newly-formed Radio Transmitters' Society approached the Radio Society of Great Britain and offered to co-operate. This was apparently met with a flat refusal to negotiate, and each body is now determined to pursue its own policy to the bitter end. While we may suspect the underlying causes of this rupture, we do not think it desirable to express in print any observations which would tend to aggravate the position. We believe there is sufficient good sense existing amongst the leaders on both sides to enable them to appreciate the weakness of divided effort, and to find some honourable and mutually acceptable way out of the present *impasse*. The names associated with the formation of the new Transmitters' Society are sufficient to stamp it as a responsible and seriously minded body. They are not the kind of people to fly off at a tangent because of some imaginary grievance against the Radio Society of Great Britain; the fire which causes the smoke must have a real existence, and we suggest in all friendliness to both parties that negotiations for co-operation should be re-opened before it is too late. The Radio Transmitters' Society have expressed willingness and have been rebuffed; the next move is with the Radio Society of Great Britain.

A Note to Contributors.

We have to thank a number of our readers for sending us contributions on various aspects of experimental work. Some of these we have been able to accept; others we have had to return, either because the subject matter has not been sufficiently novel, or has not been sufficiently within our specialised scope. We shall always be glad to consider matter of the right kind, and, as so many of our readers must be doing original work well worthy of being recorded in our pages, we hope they will consider the possibility of sending us an article when they are trying out some new research. We make this suggestion—that, as their work progresses, they should make notes of calculations, quantities, diagrams, and other data, so that, at the completion of the research, they have the material already at hand for their article. With these notes at hand it is a comparatively simple matter to write up an interesting account of the work they have done; but if they have no exact data to go upon it means traversing the ground over again, and time for this may not be available. We pay promptly, and at good rates, for articles which are up to our standard, and are always glad to get in touch with new writers in any part of the world who have something worth while to report.

"Side-Band" Telephony.

By E. H. ROBINSON.

Much interest is now centred around the side-band system of telephony, owing to the trans-Atlantic test carried out some months ago. We understand that these tests are still being conducted, and in order that the reader may be familiar with the system we outline below the fundamental principles involved.

THE object of this article is to give a brief outline of a peculiar system of radio-telephony which, although it had its inception as far back as 1915, is little known except in highly technical circles, but which has probably revolutionised the possibility of commercial radio-telephone services. This system, or, at any rate, a modification of it, was used in the recent transatlantic telephony test which was so successfully and reliably carried out between Rocky Point and New Southgate.

In order to make clear the basic principle underlying the system about to be described it is desirable first to consider what happens in ordinary radio-telephony when we modulate the amplitude of a high-frequency sine wave (the carrier wave) in accordance with a low-frequency sine wave. Let the carrier wave be represented by A sin $2\pi\ Pt$ and the speech wave from the microphonic source by B sin $2\pi\ Qt$, P being the frequency of the H.F. oscillations and Q the mean speech or modulating frequency. Arbitrary phase angles are left out for simplicity. Fig. 1 is a diagrammatic representation of the modulated carrier wave. A represents the maximum amplitude of the carrier wave when no modulation is taking place, that is, when pure C.W. is being emitted, but which is varied in accordance with the wave B sin $2\pi\ Qt$ when modulation occurs.

The modulated carrier is, therefore, represented by—

$$A\ (1 + B \sin 2\pi\ Qt) \sin 2\pi\ Pt.$$

Which expression, by slight manipulation, simplifies to—

$$A \sin 2\pi\ Pt + \frac{AB}{2} \cos 2\pi (P - Q)t - \frac{AB}{2} \cos 2\pi (P + Q)t.$$

This shows that a modulated carrier wave may at any moment be considered as made up of three component waves corresponding to frequencies of P, (P — Q) and (P+Q). Since the audio frequency Q is usually small compared with the carrier frequency P, the three frequencies P, (P — Q) and (P+Q) will heterodyne each other in an ordinary receiver to produce a beat-note of frequency Q; that is to say, a sound whose tone and qualities correspond to that spoken or played in the microphone at the transmitter. This may seem a roundabout way of considering the action of radio-telephony, but it is actually what happens, and is a fact well known to all radio engineers.

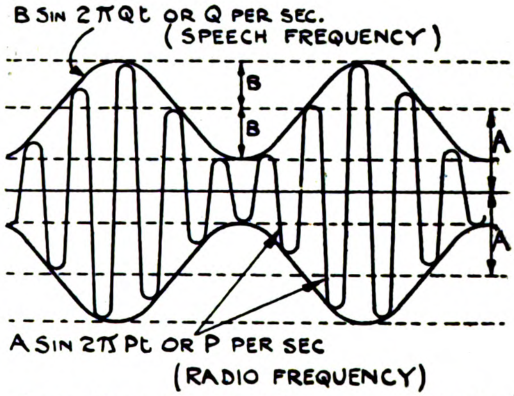


Fig. 1.—Diagrammatic representation of a modulated carrier wave.

Now it will be seen that only the side bands of frequency (P+Q) and (P — Q) are effective in carrying the telephonic message, the steady component P (represented by A sin $2\pi\ Pt$ in the above expression) only being of use to heterodyne the frequencies (P+Q) and (P — Q) at the receiving end to produce audible telephonic signals. Obviously from a point of view of economy it would be better only to transmit the side bands (P+Q) and (P — Q) and provide the heterodyning effect by a local heterodyne (consuming negligible power) at the receiver oscillating at a frequency of P. As a matter of fact it is only necessary to transmit one of the side bands, say (P+Q),

and the energy saving over the ordinary system would be very great in this case. Suppose, for example, that in an ordinary choke-control transmitter that the percentage modulation B is 100 per cent. (which, by the way, is not desirable), our steady carrier P will have an amplitude of A, while the business components (P+Q) and (P — Q) will each have an amplitude of $\frac{A}{2}$. As the energy of a wave is proportional to the square of its amplitude only a quarter of the radiated energy is carried in either of the modulated bands (P+Q) or (P — Q), most of the energy being wasted in the steady carrier P. As the percentage modulation is usually much less than 100, the usual loss is greater still. If some of the 10-watt transmitters could concentrate all their 10 watts into one of the sidebands, say (P+Q), they would have a signal strength and range about equivalent to that of a 50-watt radiophone transmitter working on ordinary lines, provided that "homodyne" reception (*i.e.*, a local heterodyne of frequency P) was used. At the same time the man next door with a crystal set would hear very little of them. Unfortunately side-band telephony would be difficult to perform on the short wave-lengths at present allowed for experimental work, but there is an open field here for the experimenter.

Methods of Separation of Side-Bands from Carrier.

The suppression of the carrier frequency and the selection of one of the side-bands cannot readily be effected on short wave-lengths by ordinary selective methods as the percentage difference is so excessively small. Suppose, for example, that telephony is being done on a wave-length of 300 metres; this corresponds to a frequency of 1,000,000 oscillations per second. The mean speech frequency Q is of the order of 1,000 oscillations per second, so that the three waves emitted when modulation occurs have frequencies of 999,000, 1,000,000 and 1,001,000. The difference is only 0·1 per cent., and can hardly be detected on an ordinary tuned receiver. On a wave-length of 3,000 metres (frequency 100,000) the difference would be 1 per cent., but even here separation by ordinary tuning would not be easy. On 30,000 metres—that is, at a carrier frequency of 10,000 per second—the difference would be 10 per cent., and separation could be effected by ordinary selective methods; but such low carrier frequencies as this are practically useless for direct radio transmission. It has also to be borne in mind that the speech frequency Q is not any one definite frequency, but is a very complicated mixture of frequencies ranging from about a hundred to several thousand per second. Hence the side frequencies (P+Q) and (P—Q) are really bands whose width is that of the audible range and which merge into the central carrier P. Q merely represents the mean speech frequency for purposes of argument.

A very ingenious method of suppressing the central carrier frequency and selecting one of the side modulated frequencies was invented by Carson* in 1915 and modified later by Hartley.† The schematic arrangement is shown in Fig. 2, and its method of functioning depends upon the fact that the input-output voltage characteristic of a three-electrode valve is not a straight line, but is a curve which may be represented by the equation—

$$E_1 = av + bv^2 + cv^3 + dv^4 \quad \ldots \ldots (1)$$

where v is the input voltage applied to the grid circuit and E_1 the voltage set up in the output circuit; a, b, c and d being constants depending upon the valve in use. Suppose now we have two valves V_1 and V_2 with identical characteristics arranged as in Fig. 2, with a common output circuit, but with the input circuits in opposition to each other. If v is the input voltage on the grid of one of the valves V_1, the voltage E_1 which V_1 tends to set up in the output circuit L_3 is that indicated by equation (1). But the other valve V_2 is connected so that the input voltage v produces an opposing effect in the valve V_2, which tends to set up a voltage of E_2 in the output circuit L_3, where—

$$E_2 = a(-v) + b(-v)^2 + c(-b)^3 + d(-v)^4;$$
$$i.e.,\ E_2 = -av + bv^2 - cv^3 + dv^4 \quad \ldots \ldots (2)$$

The net effect in the output circuit is the sum of the two voltages E_1 and E_2 obtained by adding equations (1) and (2).

$$E_1 + E_2 = 2bv^2 + 2dv^4.$$

* J. R. Carson. Brit. Pat. 102,503.

† R. V. L. Hartley. Brit. Pat. 151,928.

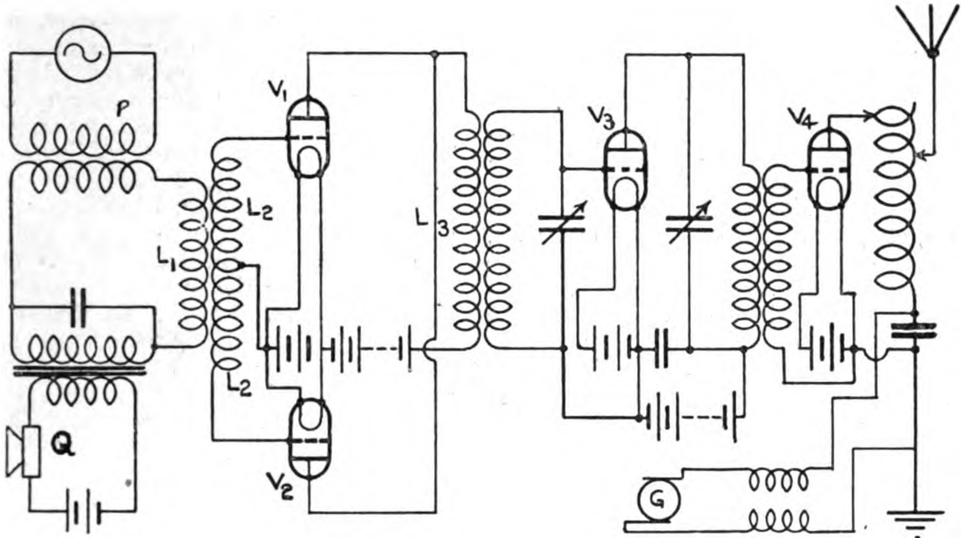


Fig. 2.—The Carson-Hartley system of radiating only the side-band component employs two opposed three-electrode valves to balance out the carrier frequency.

The term $2dv^4$ is, or may be made, negligibly small, and for practical purposes may be neglected.

Therefore—

$$E_1 + E_2 = 2bv^2 \quad \ldots\ldots\ldots\ldots \quad (3)$$

Hence all effects cancel each other in the output circuit L_3 except that which is proportional to the square of the input voltage. It is desirable, therefore, that the valves V_1 and V_2 should have a characteristic curve with a pronounced parabolic component. A little further consideration with reference to Fig. 2 will show how the arrangement illustrated therein serves to eliminate the carrier frequency. High-frequency oscillations from a master oscillator O and audio-frequency oscillations from the microphone M are induced into a common circuit containing an inductance L_1 coupled to the input circuit L_2 of the valves V_1 and V_2 so that the H.F. and L.F. potentials are both applied to the grids. L_2 is a centre-tapped inductance, the centre tap being connected to the common filament junction and the extremities being connected to the grids. This part of the apparatus must be symmetrically arranged if the desired balancing effect is to be obtained.

On each grid two sets of oscillations are being simultaneously applied, one at radio-frequency P, which may be represented by $A \sin 2\pi Pt$, and the other at audio-frequency Q, which may be represented by $B \sin 2\pi Qt$. The input voltage v at any moment is, therefore, given by—

$$V = A \sin 2\pi Pt + B \sin 2\pi Qt.$$

We see from equation (3) that the output voltage across L_3 is $2bv^2$; that is—

Output voltage

$$\begin{aligned} E &= 2b\,(A \sin 2\pi Pt + B \sin 2\pi Qt)^2 \\ &= 2b\,(A^2 \sin^2 2\pi Pt + B^2 \sin^2 2\pi Q \\ &\quad + 2AB \sin 2\pi Pt \sin 2\pi Qt). \end{aligned}$$

Which by gentle manipulation becomes—

$$\begin{aligned} E &= 2b\,A^2\,[1 - \cos 2\pi\,(2P)t] \\ &\quad + 2b\,B^2\,[1 - \cos 2\pi\,(2Q)t] \\ &\quad + 2b\,AB \cos 2\pi\,(P - Q)t \\ &\quad - 2b\,AB \cos 2\pi\,(P + Q)t. \end{aligned}$$

This last expression contains four terms, and shows that four frequencies are found in the output circuit L_3, namely:—

(*a*) A frequency of 2P; that is, twice the carrier frequency P generated by the oscillator O. This frequency, which is really a kind of second harmonic, is far removed from the working frequencies, and will not be passed on to any appreciable extent.

(*b*) A frequency of 2Q is equal to twice the frequency generated by the microphone M. This being audio frequency it will not affect the subsequent radio circuits.

(*c*) A frequency of (P+Q).

(*d*) A frequency of (P — Q).

It will be seen that the carrier frequency does not appear at all in L_3 if the circuits

have been properly balanced. We have now only the frequencies (P+Q) and (P — Q) to deal with, and one of these, say (P+Q), is selected by the tuned circuit L_4, amplified by the power amplifying valves V_3 and V_4, and thence passed to the radiating system. Various details which would be necessary in practical working (such as grid potentiometers, etc.) have been omitted from Fig. 2, which is only intended to illustrate the principles involved.

In another method of eliminating the carrier frequency due to Osborn* a somewhat different principle is used. By the use of an auxiliary frequency intermediate between the speech frequency Q and the transmission (N+Q), is selected in this manner, and is, in turn, made to modulate the output of a second oscillator O_2 working at the transmission frequency P, which may be of the order of hundreds of thousands per second. The usual analysis shows that three frequencies P+(N+Q), P and P — (N+Q) will be produced, and if N has been suitably chosen there will be sufficient difference to enable one of the bands P+(N+Q) to be selected from the rest and passed on to the amplifier A. Thus, if the transmission frequency P is 100,000, N 10,000, and Q 1,000, the three frequencies will be 111,000, 100,000 and 890,000, which differ by more than 10 per cent. and present no particular difficulty

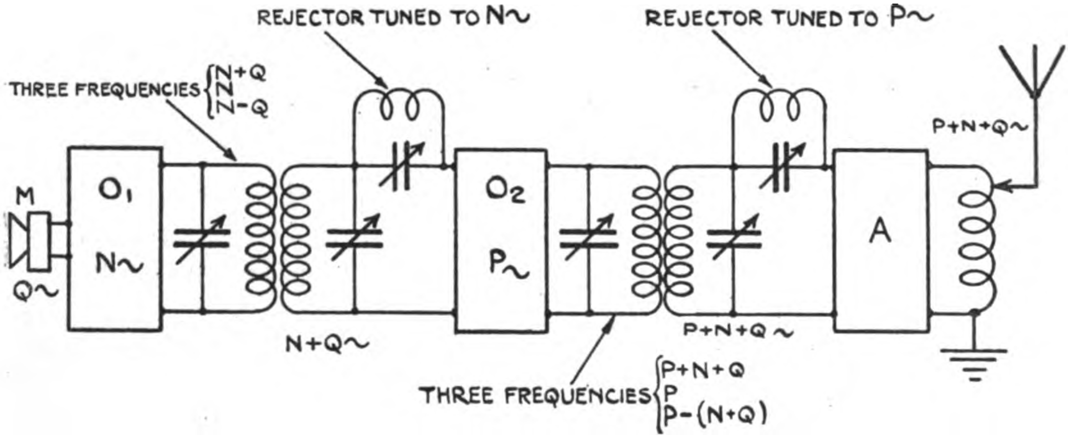


Fig. 3.—Osborn's method for eliminating the carrier frequency employs one or more intermediate frequencies, which enables sufficient separation to be obtained by means of tuned circuits.

frequency P the side-bands are sufficiently separated from the carrier to allow of the selection of one of the side bands by ordinary tuned circuits. Fig. 3 serves to show the general scheme of Osborn's method. Audio-frequency currents from the microphone M are made to modulate oscillations of frequency N generated by a low-power oscillator O_1. N is a comparatively low frequency which may be just at the upper limit of audibility, say 10,000 per second. As previously mentioned, it is quite possible with a frequency of this order to separate the frequencies (N+Q), N and (N — Q) by means of suitable tuned acceptor and rejector circuits (Q being the mean speech frequency). One of the modulated frequencies, say to ordinary tuning methods. A frequency of 100,000 corresponds to a wave-length of 3,000 metres, which is rather long, and if side-band transmission is contemplated on short wave-lengths it may be necessary to use a second intermediate frequency in order to obtain sufficient separation of the modulated bands from the carrier at the transmission frequency.

It will be seen that in either Carson's or Osborn's method nothing is radiated while the microphone is not being spoken into. In each case the master oscillator, which is generating oscillations all the time, may be of very low power, say a few watts; since its oscillations, when unmodulated, are not passed on to the power amplifier nothing is radiated. In fact, side-band

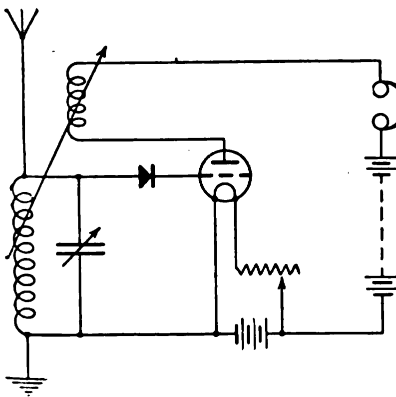
* H. S. Osborn. U.S. Pat. 1,361,488.

telephony is, amongst other things, a quiescent aerial system, and is the only quiescent aerial system which can be made free from serious distortion. If suitable intermediate amplification is used the final valve or valves associated with the aerial may be made to handle a power of several kilowatts.

Side-band telephony, when compared with the ordinary radio-telephony to which we are accustomed, presents some very peculiar features. First, it is inaudible, or, at any rate, quite unintelligible, in an ordinary receiver unless heterodyned; this, of course, is quite the reverse to ordinary telephony. The necessary local oscillator must be tuned exactly to the frequency P of the master oscillator *a*, the transmitter, so that it heterodynes the incoming frequency (P+Q) to give a beat note of the original speech frequency Q. This is known as "homodyne" reception, and allows us to avail ourselves of the advantages which beat reception, as is common knowledge, will bring in a weak station that cannot be heard unheterodyned. A second point is the enormous saving in power made possible by the fact that large amounts of energy need only be drawn from the power supply by the power valves when and as required by the speech; also a great deal of the heating up of the valves may be eliminated owing to the quiescent intervals. A third feature, and one which presents great advantages, is the reduction of interference due to the fact that the band of frequencies monopolised by the transmission from a width of over 2Q to a width of Q. Thus in a given band of wave-lengths we could crowd in twice as many stations working on the side-band system as we could stations working on the ordinary system.

In spite of its advantages, side-band telephony is not likely ever to be used for broadcasting purposes owing to the extra complications involved and the necessity for an extremely accurately adjusted homodyne at each receiving station. The effect of a slightly mis-tuned homodyne would be something like a gramophone running at the wrong speed, only it would be worse, as the relative pitches of different notes would be all wrong. The utility of the system lies mostly in the direction of commercial telephone services on long wave-lengths, but the whole subject presents a fascinating and practically unexplored field for the experimenter who is limited to short wave-lengths.

Crystal-Valve Circuits.



The use of a crystal rectifier connected directly to the grid of a subsequent amplifying valve is well known, and has been described in the pages of this journal. The circuit shown here has been used for some considerable time by Mr. H. Nicholson, and there seems to be some doubt as to the mode of operation. Reaction is obtained magnetically in the usual manner, and the circuit may be made to oscillate. The circuit has not yet been examined for grid current, and it is not known whether the valve or the crystal acts as the rectifier. The functioning of the circuit is wholly dependent upon the adjustment and direction of the crystal, and we should be glad to hear of readers' experiences with it.

The Principles of Choke Control.

By L. E. OWEN (2VS.).

While the system of choke control is very popular amongst experimenters it seems that many are not fully acquainted with the mode of operation, and consequently they cannot operate their apparatus efficiently. The following simple article should remove all difficulties.

TO the experimenter who has studied various methods of control for the purpose of impressing speech frequencies on to the output circuit of a continuous wave generator, it is proposed to offer the following resumé of the practical experience gained in three years of experimental work carried out by the author.

Many experimenters may be heard discussing the merits of choke control, both at debates of the local societies and also during the rather infrequent periods when those of the cult are allowed to make the ether horrid or otherwise, and the general trend of opinion seems to be that theoretically it is electrically a very beautiful circuit, but that "Jones and myself get much better modulation on such-and-such a form of control."

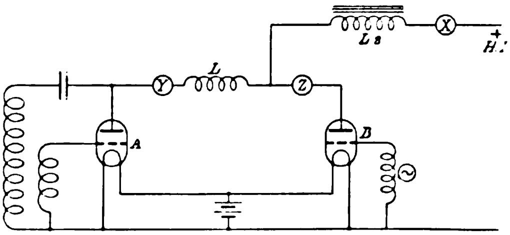


Fig. 1.—The fundamental choke control circuit.

This is quite probably the case, as there is no system of control so hard to get to a really efficient state, and at the same time be it remembered there is no system capable of giving better results from all standpoints than the constant-current choke control. The author will attempt, therefore, to explain the technical and other difficulties that must be overcome in order to obtain good speech and a large percentage of control without sacrificing the quality which seems generally to be lacking in many such operated stations to be heard in the free periods between broadcasting.

Firstly, it should be understood that it is better to modulate properly a large percentage of a relatively small high frequency aerial output, than to have a carrier wave which strikes the listener-in with a horrid thud and having a very small percentage of modulation. For this reason it is better to employ a valve for controlling having a rated output of at least one-and-a-half times the value of the valve used as an oscillator, as any attempt to overload the control valve results in poor speech, the magnification of parasitic noises generated in the microphone system, and other sources of an undesirable low frequency genus.

Consider diagram No. 1. It will be noted that the circuit is purely a diagrammatical one, showing the anodes grids and filaments of two valves A and B being connected through the radio frequency choke L, and fed by a source of high voltage, which passes through an iron-core choke L2 ; the valve B is shown to have a source of alternating potential, available across its grid filament system. Three milliammeters are included, as shown at X, Y, and Z.

Let us consider the function of the various parts of the circuit beginning at the choke L2. This choke being iron cored presents a definite impedance to sudden changes in the feed current which passes through it to the valves, and its function is to prevent any more current passing to the valve system than that amount which normally passes to each valve when A is in a state of oscillation and B in a quiescent state, *i.e.*, is not being modulated by low-frequency pulses in its grid circuit.

It follows, therefore, that if the grid of the control valve B is made more positive at any given instant an increase of current will take place in the plate circuit of valve B. Now the plate current of the valve A, owing to the valve being in a state of oscillation, is absorbing a definite amount of current, and were it not for the fact that the iron-cored choke L2 offers impedance to changes

in the flow or currents, this extra current would naturally come from the high voltage supply. We have seen that the impedance of the choke prevents this, and therefore the extra current has to be absorbed from the plate circuit of valve A.

Conversely, if the grid of valve B is made more negative at any instant, the result will be a *decrease* of its plate current and a corresponding *increase* of current in the plate circuit of the oscillator valve A, the choke L2 again acting as a time switch (or impedance to the change in current) which prevents the unwanted currents from the plate circuit of the control valve from flowing back to the source of high voltage energy.

To sum the position up briefly, at any instant any deficit of current in the plate circuit of the control valve occasioned by increase of the positive grid potential must come from the available current in the plate circuit of the oscillator valve. Conversely, any rejected anode current from the control valve must be forced into the plate system of the oscillator valve. These additions and subtractions of current derive their impetus from the differences of potential set up across the choke L2 while exerting its function in the circuit. It is from the action of the choke L2 that the circuit is given the name of the constant-current choke control. We shall next consider the position of the three milliammeters X, Y, and Z. The milliammeter X will register a total feed current, and for the reason that the circuit is a constant current one, *i.e.*, the total current supplied to the valves is always the same, it follows whether modulated by speech or otherwise the reading should not vary at all; this point is mentioned as the author has quite often seen variation of this current alluded to quite gleefully as a sign of good modulation. Modulation it is, certainly—that is, the grid circuit of the control valve is affecting its plate circuit, but the changes in current so produced are doing exactly what the aim of the circuit is to prevent, and merely shows that choke L2 is not functioning as it should.

The milliammeters Y and Z should register as follows:—If we take as a basis of argument, two valves of the same dissipation capacity, it is obvious from a theoretical view-point that the best proportion of current should be half for the oscillator valve and half for the control valve, when valve A is in a state of oscillation and valve B in quiescent state, so that when speech is impressed on the grid circuit of the valve B, it either absorbs practically all the available energy from valve A and in that case causes it almost to cease from oscillating, or again gives up all its energy to valve A and therefore to increase the amplitude of oscillations. Such magnitude of control would produce very poor quality speech, and also the control valve would be greatly overloaded, and it is, therefore, best in practice to cause the oscillating valve A to take about two-thirds when on the proper point of its characteristic curve, and the control valve one-third, this wattage being approximately one-third to one-fourth of the normal working load of the valve. For the 10-watt set the author would recommend a proportion of the following order:—

Input volts on load, 800; constant current milliammeter X, 12·5 ma; sub-feed to oscillator at 8·5 ma; sub-feed to control, 4 ma.

The R.M.S. input to the plate would therefore be somewhere in the nature of 8 watts, provided that the control valve is worked at the proper point of its characteristic curve.

Owing to the fact that the frequency of the speech may be about 1,000 cycles, the ammeters Y and Z would not indicate the control, except on certain persistent vowel sounds such as "O" and "E" when the addition or subtraction effect on the meters Y and Z should be just visible; if it is desired to see the effect of modulation, an electrostatic voltmeter of low capacity should be connected across the plate filament circuit of each valve. Alternatively, a neon tube may be connected by one of its terminals to the anode of the oscillator.

The secrets of the choke control system are these: First, proper design of the choke, and, secondly—and most difficult—to induce the control valve to work on the most efficient point of its characteristic curve.

We will now consider the question of the control valve characteristic curve. Take, for example, Fig. 2. We have here anode current—grid volt curves of the same valve at different anode potentials. On curve A, if the base line of the grid is zero volts it

follows when modulation occurs by the grid potential changes, owing to the zero line being near saturation, increment modulation will be obtained, *i.e.*, an increase of plate current in the oscillator, with a tendency for decrease of the grid current in the control valve. Again, at the curve C the reverse will be found to occur. Now at B fairly good modulation will be obtained, owing to the fact that both decrement and increment of the plate current of the oscillator is taking place; the one disadvantage being that grid current on the control valve of a high mean order will occur in one half cycle this causing poorness of quality by distortion, but, on the other hand, fairly full modulation of a sort will be obtained.

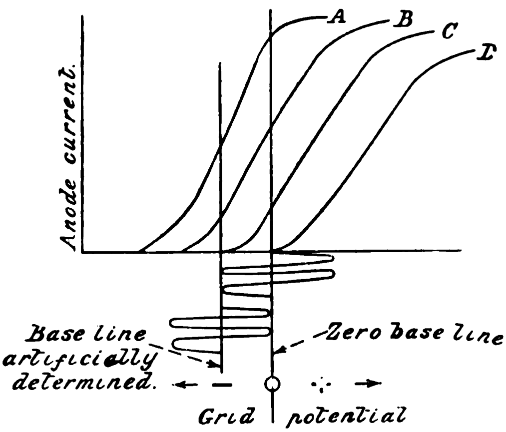


Fig. 2.—The family of curves indicates the correct operation point for proper modulation.

Next consider curve D. This shows that practically no modulation can occur and is usually the condition that the valve is working under when very broken speech is radiated; decrement modulation of the oscillator being present to excess.

It is therefore fairly obvious that the best possible speech will be obtained if the base line of the control valve grid be artificially determined on a curve, so that the valve be worked in a manner so as to produce equal decrement and increment modulation, while keeping the grid current at its lowest mean possible value. This can best be obtained by giving the control valve grid sufficient negative potential from a battery so as to indicate the conditions found in curve B on curve A; modulation will then be obtained under the best possible conditions, *i.e.*, full modulation without distortion due to excessive grid current.

Lastly, it is proposed to offer a few suggestions on the choke L2. The impedance of any given iron-cored inductance is obtained in practice by the following method. A known current is passed through the choke, and the potential drop across the choke is read off on a meter adjusted for the particular frequency. This inductance is then given by

$$L = \frac{E}{2\pi f I}$$

Now in this case what is required is a choke which will offer its maximum impedance at the R.M.S. value of speech frequency, which may be said to be for all-round purposes 1,000, allowing that a man's voice will be a slightly lower R.M.S. frequency—say, 850.

Now knowing our feed current, say, a maximum of 15 milliamps., we have to design a choke which will impede any change in this current at 850 cycles, after allowing for the losses in iron and losses in the winding of the choke. Now the inductance required for those figures is, viz.,

$$L = \frac{800}{6{\cdot}28 \times 850 \times {\cdot}015} \qquad L = 100 \text{ Henries.}$$

Therefore, we take a core ½" diameter, with about 5" winding space, for which 15,000 turns of 38 gauge silk-covered wire will be required. This choke will be found to give very clean and full modulation on the power we have discussed, *i.e.*, 10 watts, and may have a D.C. resistance of about 1,000 ohms. The drop of volts across this choke will be—

$$\begin{aligned} E &= RI \\ &= 1{,}000 \times {\cdot}015 \\ &= 15 \text{ volts.} \end{aligned}$$

This will not be worth worrying about.

It has not been the purpose of the author to design a choke control set, but rather to show the fundamental principle employed in its operation, and it is hoped that this article may be the means of giving a clear insight to those who have had difficulty in making a success of this interesting method of control.

Magnetically-controlled Valves.

BY H. ANDREWES, B.Sc., A.C.G.I., B.I.C.

The magnetic control of valves seems to be a subject which has received very little attention amongst experimenters. Below will be found a brief outline of the manner in which a magnetic field can be made to influence the electronic emission in an ordinary three-electrode valve, and some interesting experiments are suggested.

AS long ago as May, 1921, and this is a long time from the radio point of view, magnetically controlled valves were introduced to radio engineers, but, as far as the radio experimenter, or "amateur" as he is called for some unknown reason, is concerned, very little seems to have been published in this interesting field of research.

This last fact is, I think, partly due to the belief that any experiments on these lines required special valves and special apparatus. The object of this article is to remove to a certain extent this belief, and show that a large number of interesting experiments may be performed with the apparatus usually available to the experimenter.

Let us first consider very briefly the work which has been done. In May, 1921, A. W. Hull, of the G.E.C. of America, delivered a lecture to the American Institution of Electrical Engineers on a new vacuum tube device which he had invented and called the Magnetron.

The magnetron* consisted essentially of a symmetrical diode, *i.e.*, a cylindrical anode with a central straight filament to which a magnetic field was applied, parallel to the axis of symmetry, in this case the filament.

In its simplest form the action of this tube is then simply a "valve" or relay. If no magnetic field exists a current will flow from cathode to anode, its magnitude depending on the temperature of the filament and the anode potential, the direction of flow being of course radially outwards from the filament. If now a magnetic field is applied, and if it is weaker than a certain critical value no effect is produced, but if stronger than this value a proportion of the electrons emitted from the cathode will be deflected and prevented from reaching the anode. If the field is sufficiently strong the anode current may be completely stopped, the action corresponding with the closing of a valve or the opening of a relay.

It is obvious then that curves may be plotted, characteristic of the tube, between anode current and the magnetic field applied. The shape of such a curve is shown in Fig. 1.

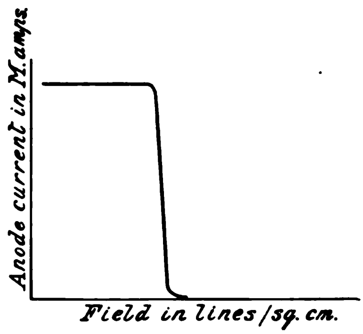


Fig. 1.—Here it is seen that at a critical field strength the anode current is reduced approximately to zero.

It will be seen that this curve is very steep at the critical field strength. The field strength required to stop the anode current depends, of course, upon the diameter of the anode, that is to say, the length of the electron path. It has been found that the field strength required varies inversely as the anode diameter.

The value of this critical field may also be calculated from the formula :—

$$H = \frac{\sqrt{8\frac{m}{e}V}}{R}$$

or putting in values for e.f.m. the charge and mass of an electron

$$H = \frac{6{\cdot}72}{R}\sqrt{V}$$

In the case of a V24, this value of H works out at about

96 lines/cm²

taking an anode voltage of 25.

* *Journal A.I.E.E.* Vol. XL, No. 9. Sept., 1921.

Now it is obvious that this principle, that is to say, the application of a magnetic field, may be applied equally well to a triode as to a diode, provided the symmetry is kept. Hence we see that provided a suitable means of attaining the necessary flux density can be found, an ordinary valve, those such as the Ora and V24 may be experimented with.

With a view to finding out how practical this idea was the author has carried out a few experiments with the Ora valve.

Experiments with the Ora.

As the valve used is a triode it is obvious that diode magnetron curves cannot be obtained as the potential of the grid will affect the shape. Hence curves where taken for anode current—field strength with different grid potentials.

The circuit used for these curves is shown below in Fig. 2. The field coil used was of an extremely rough and ready nature. A photograph of the arrangement is shown in Fig. 3.

The coil used was really very unsuitable but was the only thing available at the time. The turns on the coil were in two sections of 5,000 each, the two sections being placed in parallel to reduce the D.C. resistance.

In this way about 1,200 ampere turns were obtained.

Fig. 4 shows the curves obtained for different grid voltages.

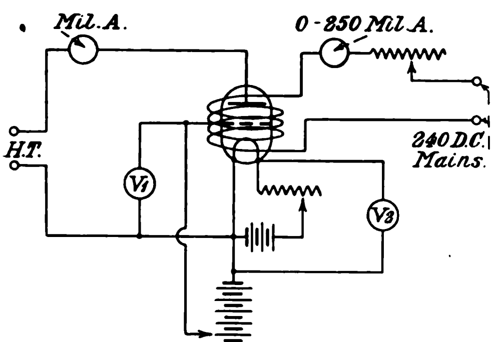


Fig. 2.—The circuit used to obtain the curves shown in Fig. 4. The field strength was varied by means of a resistance in series with the field coil.

These curves show several very interesting points. Perhaps the most obvious thing that one notices is that as the grid is made positive, we see that the cut-off of anode current is much more rapid, that is to say, the curve becomes much steeper. This is rather what might be expected, for as the grid becomes positive grid current commences, the negative space change is reduced, and hence the grid is acting with the magnetic field in stopping electrons emitted from the filament (which do not actually hit the grid) from reaching the plate.

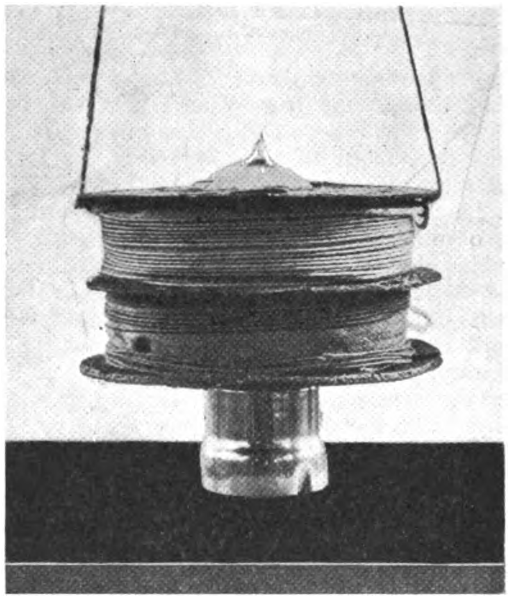


Fig. 3.—The field coil consisted of two sections of 5,000 turns connected in parallel to reduce the resistance. These were connected to 240-volt mains, and a strength of about 1,200 ampere turns was obtained.

The reader will perhaps excuse this not very conclusive explanation, as it is not proposed to delve deeply into the theory of the magnetron since it is much too complicated for a brief explanation such as could be given in a short article.

Applications.

Turning now to possible application of this device, obviously such an arrangement can be used in the same manner as a triode, as a rectifier, or as an amplifier of H.F. currents.

Rectification can be obtained by using the bend in the curve shown in Fig. 4. If, for example, the curve corresponding with $+7 \cdot 2$ Vg. is used and a polarising field of 500 amp. turns was used, by coupling a coil carrying H.F. to the field coil, rectification could be obtained. Again, by working in

the centre portion of the curve amplification of H.F. currents could be obtained in a similar manner.

Unfortunately, with such conditions, neither of these arrangements would work very well, as bad distortion would be introduced due to grid current. This current is, of course, necessary to obtain a steep curve and good amplification. Obviously, to obtain good distortionless amplification a diode valve must be used, and such an arrangement is given in the original paper by A. W. Hull.

The magnetron may also be used as a generator of H.F. (or L.F.) currents. This may be done either by using a feed back arrangement between the anode current and magnetic field circuits or by using the grid as well and obtaining an effect similar to the

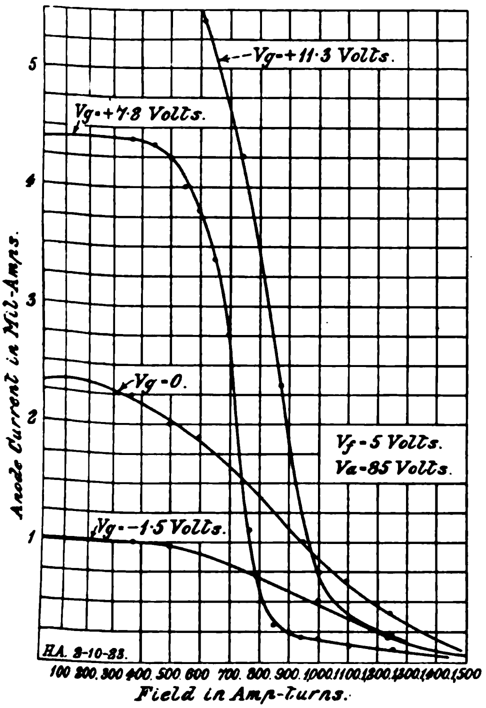


Fig. 4.—Some characteristic curves obtained with an ORA valve. The curve obtained with a grid voltage of 7.2 volts is suitable for rectification.

"negatron." Using the magnetron as an H.F. oscillator it is found to be very efficient and may be used for the control of large amounts of H.F. energy.

Another application which has occurred to the writer is its use in telephony. As we may regard the magnetic field as a second control electrode, it would be possible to use one control electrode to produce the necessary H.F. currents and modulate with the second electrode, obtaining the same effect as in a double grid valve. The best arrangement is probably to use the magnetron oscillator circuit and modulate the grid potential, but the other arrangement is shown in Fig. 5, in which an Ora valve is used as a master oscillator to control a main power valve, modulation being obtained by varying the flux of the magnetic control.

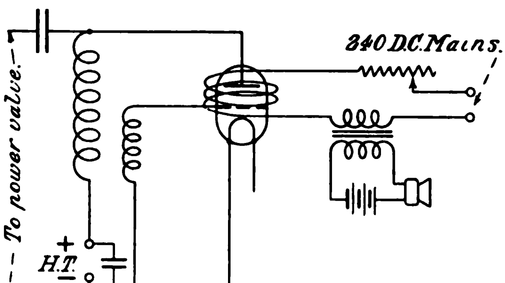


Fig. 5.—The valve is here used as a master oscillator, and controls the main power valve of a telephony transmitter. The valve is further controlled by a magnetic field in the manner previously indicated, modulation being effected by varying the field by microphone potentials.

Although the magnetron originally was a highly evacuated tube, it is interesting to note that similar gaus-ampere curves may also be obtained for "soft" valves.

The author has even succeeded in obtaining similar curves, using the now famous neon lamps.

It should also be possible to obtain very interesting results using a valve, such as the Cossor, so that the field could be applied parallel and not at right angles to the electron flow.

Finally, the writer would like to point out that this article is intended in no way to be the last word on the subject, or to "tell you all about the magnetron." It is intended to be more an incentive to experimenters to work on this device as high hopes may be entertained for the results obtainable. It is to be hoped that other experimenters will help the writer by criticising or confirming the results which he has so far obtained.

The Construction and Manipulation of Wave-Meters.

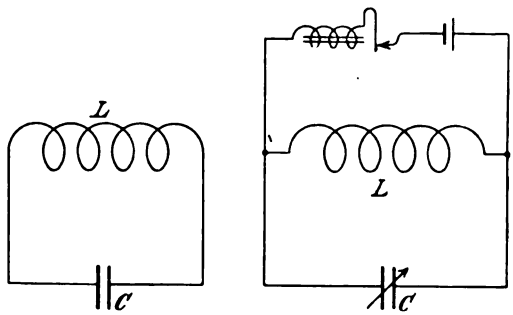
By LEONARD A. SAYCE, B.Sc., A.I.C.

For some unknown reason wave-meters seem to have received little attention by many experimenters. Below will be found a general discussion on the subject, including simple methods of calibration and constructional data.

IT is surprising how few amateur stations include a wave-meter amongst their equipment and how few amateurs realise what they are losing by dispensing with this most useful accessory. A wave-meter is easy to make and once made is in constant use whenever a new piece of apparatus requires to be tested or a transmitting or receiving set adjusted. By its aid condensers and inductances may be measured and experiments may be performed with scientific precision. In the remarks that follow an attempt has been made to show how some of these operations may be carried out and some constructional hints are given.

A wave-meter consists essentially of an oscillatory circuit that may be set into oscillation at a known frequency. Such a circuit, Fig. 1, consists of a condenser C and and inductance L. Its wave-length may be altered either by altering C or L, but, although the variable inductance method is successfully applied to the well-known Townsend wave-meter, there are certain disadvantages to this method and it will usually be found more convenient to employ a variable condenser, varying the inductance in steps if a long range of wave-length is to be covered.

Wave-meters are of two kinds—"Buzzer" and "Heterodyne"—and these correspond to spark and C.W. transmitters, respectively. If a buzzer, together with a cell to work it, is connected to the oscillatory circuit in the manner shown in Fig. 2 a train of oscillations is set up in the circuit LC every time the buzzer circuit is completed by the vibrating armature and the frequency of these oscillations is dependent upon the values of C and L. The wave-meter is said to be calibrated if we know the frequency or wave-length corresponding to every setting of C. But a variable condenser and a single inductance would provide only a limited range of wave-length, so it is convenient to have a number of interchangeable inductances and arrange them so that the minimum wave-length with one coil is well below the maximum obtained with the size smaller, so that we may have no gaps in our range. Thus, if we use a ·001 mfd. condenser and honeycomb inductances, the No. 50 coil will give a range of 250 to 800 metres and the 150 coil a range of 700 to 2,000 metres. It is thus evident that very few coils are necessary



Figs. 1 and 2.—On the left is a fundamental oscillatory circuit, which on the right is seen excited by a buzzer.

to cover a very large belt of wave length, far fewer than would be required to tune an aerial circuit through the same range because in that case we have to contend with the invariable and rather large capacity of the aerial to earth. Little need to be said as to the actual construction of a buzzer wave-meter; it is so simple that it is hard to go wrong. The buzzer should, however, be such as to give a quiet and high-pitched note and should be muffled in a small felt-lined box so that it is inaudible. It is very advisable, too, to shunt its windings with a non-inductive resistance and a flash-lamp bulb is very convenient for this purpose for it provides, in addition, a useful indication of the correct adjustment of the buzzer. The

variable condenser, buzzer, flash-lamp bulb, dry cell—to drive the buzzer—and a small switch should be mounted in a suitable box. The socket for the plug-in coils may be on the box too, but it is much better to connect it to the box by a flexible coupling, for this enables us to induce our wave-meter signals separately into the various circuits of our receiver.

The calibration of our buzzer wave-meter is done as follows :—With your receiving set tune in all the stations whose wave-

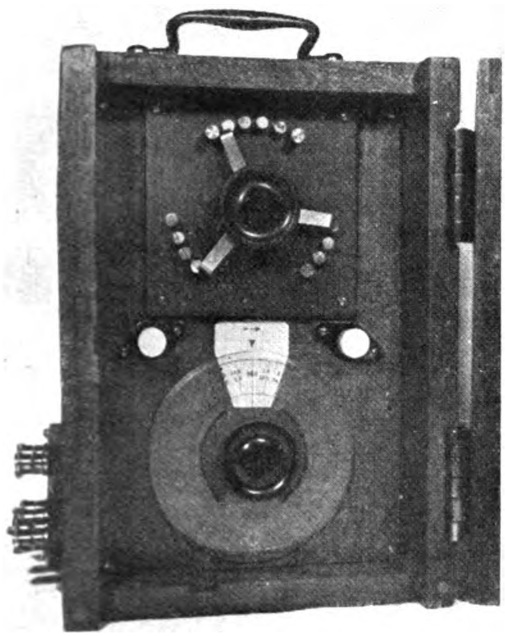


Fig. 2.—A general view of the heterodyne wave-meter.

lengths you know, both C.W. and spark, being very careful that it is the fundamental and not a harmonic that you are hearing and that C.W. stations are tuned in to their "silent points." Suppose, for instance, that you have tuned in the Paris "U.R.S.I." signals as accurately as possible. Keeping the receiver at this setting, start the buzzer and hold the wave-meter coil near the earth lead. If this coil is of suitable value the note of the buzzer, as heard in the 'phones of the receiver, will increase to a maximum intensity and then die away again as the condenser knob of the wave-meter is turned. The setting at which the intensity of the buzzer note is a maximum is when it is emitting waves of the length to which the receiver is tuned—in this case 2,600 metres—and a table should be made out as follows :—

Coil No.	Condenser Degrees	Wavelength Metres
250	45	2,600

The above procedure should be repeated on as many wave-lengths as possible. There is no need to go much above 3,000 metres, for on high wave-lengths it becomes impossible to judge the "maximum" at all accurately owing to the increasing decrement of the circuit.

Having now made as many entries as possible on our table, we must take a sheet of squared paper, dividing the horizontal axis into condenser degrees and the vertical axis into wave-lengths in metres up to about 3,000 metres. Taking all the entries for each coil in turn, plot them upon the squared paper and join them by even curves, taking a separate curve for each coil. Any irregularity in the curves will be due to the fact that many stations do not keep to their correct wave-lengths and an allowance must be made for this. To most experimenters the range from 150 to 450 metres is of great interest, and the curves for this range should be drawn on a larger scale than the others. The broadcasting stations give a number of points between 350 and 425 metres and their first harmonics a number between 180 and 210 metres, so there are quite sufficient to give quite a good curve throughout the whole range, for any inaccuracies in wave-lengths are shown up when recorded graphically.

When we have calibrated the wave-meter we are in a position to measure the wave-length of any station within its range or to tune our receiving set to any desired wave-length. Suppose, for instance, that we are 300 miles from 2LO and wish to tune him in on a very selective circuit (and we *do* need selective circuits on the North-East coast !). Of course, we might use "stand-bi and tune" switches, but it is quicker to use a wave-meter. Suppose that the circuit is as shown in Fig. 4. The wave-meter is made to emit wave trains of 369 metres and its coil is first placed near circuit A. The latter is tuned until the wave-meter signals

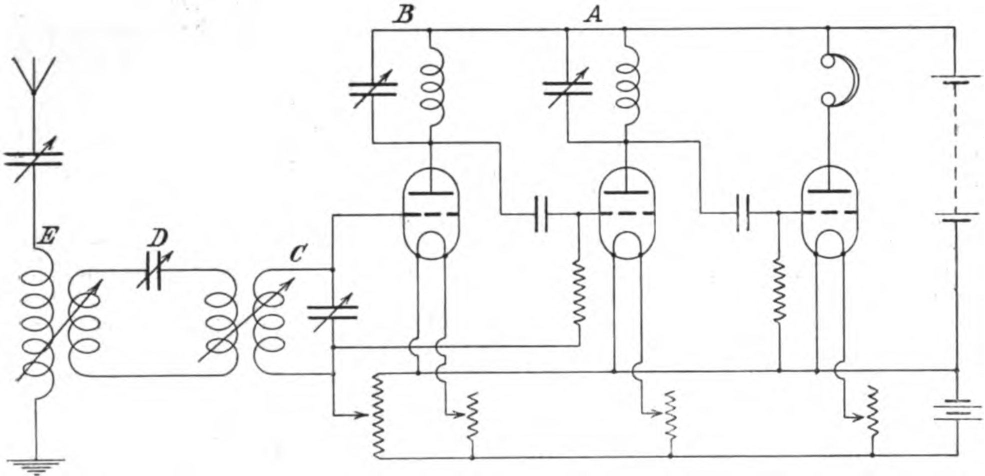


Fig. 4.—Illustrating the manner in which the multiple-tuned receiver is adjusted. The circuits are each brought into resonance with the wave-meter in the order indicated.

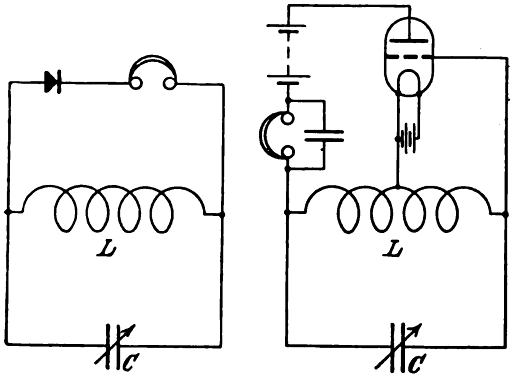
are heard with maximum loudness and then B is treated in exactly the same way. The remaining circuits C, D and E are tuned similarly and in the order given. The final adjustments and the coupling of the circuits are done with the wave-meter coil placed near to the earth lead. Always commence with the tuned circuit nearest to the telephones and do not place the wave-meter coil too near the circuit to be tuned. It is much easier to judge the "maximum" if the signals are *just* audible and if the coupling is too close there will be a serious disturbance of the wave-length.

In the rarer event of a wave-meter being required to tune a spark or telephony transmitter, the buzzer and cell are replaced by a crystal detector and telephones, thus giving the circuit shown in Fig. 5. The wave-meter has now become a calibrated crystal receiver and the inductance may be regarded as a small frame aerial. If used in connection with a 10-watt transmitter it is generally necessary to place the coupling coil quite near to the earth lead. In addition to measuring the wave-length emitted, this arrangement enables one to hear one's own telephony and so check any faults in modulation as soon as they occur.

A buzzer wave-meter is extremely convenient, but it suffers from two disadvantages: First, it is difficult to calibrate it accurately unless access can be had to a standard wave-meter, and, secondly, its accuracy, apart from the correctness of its calibration, depends on the "sharpness" of its point of resonance, and this again is an inverse function of the decrement or damping of the circuit. Even if the decrement is kept as low as possible by winding the coils with spaced litzendraht, it is not very much use at a higher wave-length than three or four thousand metres.

A heterodyne wave-meter, on the other hand, can be calibrated, if necessary, from a single reliable calibration wave, through a range of 50 to 50,000 metres. Its accuracy, particularly if it is applied to oscillating circuits, leaves nothing to be desired. It can be used both as a transmitter and a receiver and in the former capacity makes a "separate heterodyne" for receiving long waves efficiently and for using the Armstrong "supersonic" circuit on short waves. The basic circuit of a heterodyne wave-meter is shown in Fig. 6. It is only one of many possibilities, but is certainly the simplest of all. The oscillating circuit LC is exactly the same as before, but it is excited by a triode instead of a buzzer. The two ends of the coil are connected to anode and grid respectively, whilst the filament is connected to a point at, or somewhere near, the middle of the coil. An H.T. battery and pair of telephones are connected in the anode lead, but as the latter are not often needed their terminals may normally be bridged across. The H.T. battery should be about 30 volts.

Considerably less than this will serve, but alterations in the H.T. voltage vary the impedance of the valve and consequently alter the wave-length. If the voltage is fairly high, however, small changes are not so important. (In this connection, it is interesting to note, in passing, that under



Figs. 5 and 6.—In the buzzer wave-meter the buzzer is replaced by a detector and telephones, while in the heterodyne wave-meter, telephones are inserted in the anode circuit of the valve.

favourable conditions stable oscillations may be maintained without any high tension battery, provided that the positive pole of the accumulator is connected to the middle tapping of the coil.) If a four-volt accumulator is used for heating the filament no rheostat is needed. Almost any receiving valve is suitable, but a "V24" does not maintain oscillations quite so readily as an "O.R.A." or a Marconi "R." It is not advisable to use a long flexible lead for the coils, as in the case of the buzzer wave-meter, so they may be mounted in the same box as the rest of the instrument. The middle tappings of all the coils may be connected together, thereby simplifying the switching arrangements. A simple wiring diagram for a heterodyne wave-meter to cover a very large belt of wave-length is shown in Fig. 7. It is self-explanatory with the possible exception of the three-arm switch. This is an ordinary switch-arm bearing two additional arms on the same spindle clamped together in electrical contact but insulated from the spindle and the original arm by two mica washers and a small piece of ebonite tube. The coils must be of such a size that there is a fair overlap between the wave-length band of each coil and that of its neighbours. In calculating the values of suitable coils it must be remembered that the wave-length corresponds to the circuit composed of the *whole* coil and the condenser, and that the valve and its associated wiring produce minor alterations due to capacity and impedance.

The wavemeter shown in the photographs has a range of about 250 to 9,000 metres. A "polar" condenser is used, and it has a maximum capacity of ·001 mfd. A celluloid protractor, 4 ins. in diameter, is used as a dial, because the dial sold with the condenser is not of much use in the present case. The range switch is mounted on an ebonite base above the condenser dial, and the two white knobs placed half-way up the panel are respectively for adding a small mica condenser to increase the range, if this is ever needed, and for switching the valve filament on and off. The "front door" of the instrument has a small block of wood screwed to it to press in the left-hand knob and so switch off the filament, in case the door is shut whilst the valve is alight.

Four coils are used, and these are constructed as follows :—

The two lower-range coils are wound upon a cardboard former 3⅛ ins. diameter and 3 ins. long. The former for the third coil is built up from three shellaced discs of thick cardboard 3⅛ ins. diameter, and has two grooves, each 3-16ths in. wide, made from discs of three-ply wood 1 in. diameter. The fourth coil is similarly built up, but its two grooves are each 3-32nds in. wide. The windings for the coils are :—

(1) 34 turns No. 24 D.C.C. wire in a two-layer banked winding.
(2) 100 turns No. 28 D.C.C. wire in a three-layer banked winding.
(3) 380 turns No. 28 D.C.C. wire, 190 turns in each groove.
(4) 950 turns No. 36 D.S.C. wire, 475 turns in each groove.

Each coil is tapped at its middle turn. The two slab coils, Nos. 3 and 4, were placed one at each end of the cardboard cylinder holding Nos. 1 and 2, and a 2 B.A. brass rod was passed through all the coils. The projecting ends of this rod enabled the coils to be secured to the panel by two brass brackets. The above windings will be found helpful in making a similar instrument, but will

probably have to be slightly modified when tested for the presence or absence of shellac on the coils, the exact width of the slabs, and the proximity of the coils to one another are all factors which make considerable differences in wave-length.

As already stated, a heterodyne wave-meter may be completely calibrated from the observation of one reliable calibration signal. Such calibration signals are transmitted by the Air Ministry (GFA) every morning. At 0750 G.M.T. a wave of 900 metres is sent. Tune in this upon a one or two-valve receiver, without H.F. amplification, adjusting the latter to the exact point point" may extend for several degrees of the condenser. This is because the impulses induced in the receiver by the wave-meter are strong enough to force the former into resonance over quite a considerable belt of wave-lengths. When tuning in the fundamental, therefore, the wave-meter must be taken further away from the receiver until the silent point is perfectly definite. The wave-meter is now tuned exactly to 900 metres, and the setting of the condenser is carefully noted. Next, still leaving the receiver tuned to 900 metres, the wave-meter is reduced in value until the first harmonic is tuned to its silent point. It is

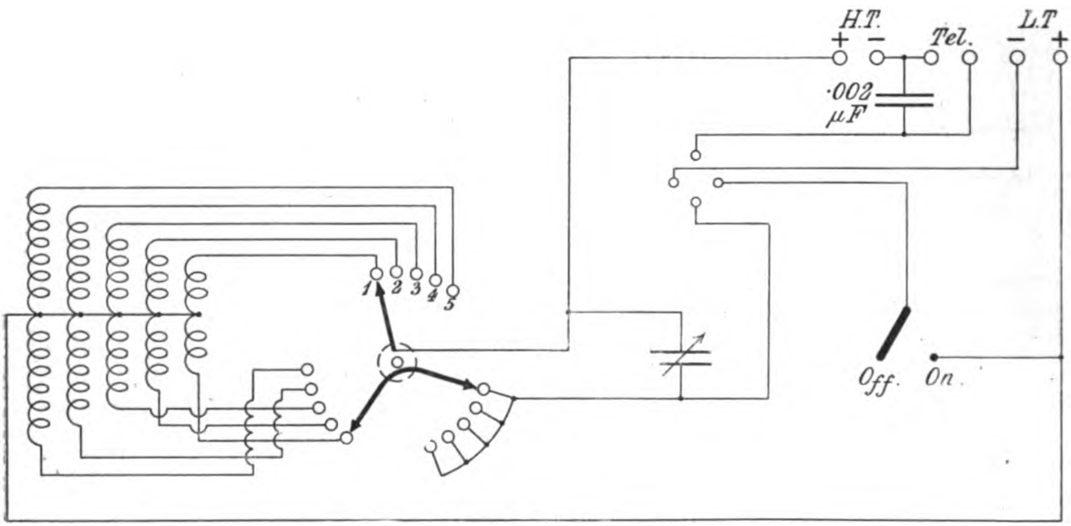


Fig. 7.—The internal connections of the heterodyne wave-meter, illustrating the special switch consisting of three arms on the same shaft, two being electrically connected, and insulated from the third.

of zero beat frequency, *i.e.*, the "silent point." Now leave the receiver severely alone but continue to wear its telephones. Switch on the wave-meter, using its smallest —No. 1—coil. The instrument should be within a few feet of the receiver, but not too near. On rotating the condenser of the wave-meter, a number of little whistling notes will be heard. Near the zero of the scale the notes will occur near together and be rather faint, but nearer the maximum they are louder and are spaced further apart. These are all harmonics of the 900 metre waves that the receiver is generating. The "fundamental" also will probably be found on No. 2 coil. It is much louder than any of the harmonics and with it the "silent now emitting a wave of 450 metres, *i.e.*, 900/2. Again note its setting and proceed to take the condenser settings at which the second harmonic, 900/3 metres, third harmonic, 900/4 metres, etc., are in tune. It would be quite easy to go as far as the tenth harmonic, corresponding, in this case, to a wave-length of about 80 metres, if the condenser had a low enough minimum capacity. A graph should be made showing the condenser settings plotted against wave-lengths and the points will be found to lie on an even curve.

To calibrate the wave-meter above 900 metres proceed as follows:—Set the wave-meter once more to 900 metres and gradually raise the wave-length of the

receiving set. At 1,800 metres a CW note will be heard. Go higher still and at 2,700, 3,600 and 4,500 metres the wave-meter will be heard again. Tune in carefully on 4,500 metres and, leaving the receiver at this setting, calibrate the wave-meter on the harmonics of this wave-length, *viz.*, 4,500/2,

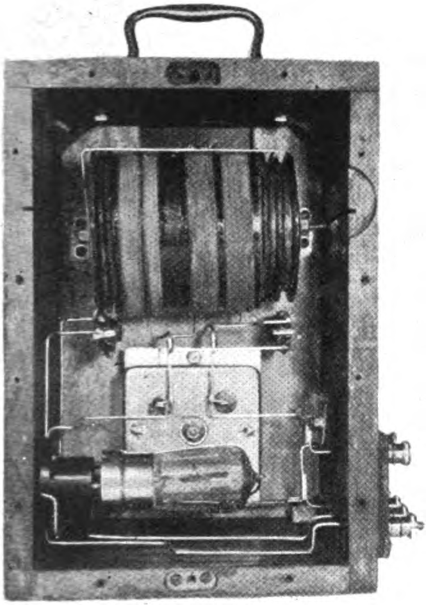


Fig. 8.—The internal wiring of the wave-meter, showing the banked winding.

4,500/3, etc., exactly as before. The fourth harmonic will, of course, be identical with 900 metres, but the 5th, 6th, 7th and 8th, will give four new points on the curves for coils No. 1 and 2, at 750, 650, 562 and 500 metres and will check their accuracy.

In a similar way we can go to still higher wave-lengths by setting the wave-meter at 4,500 metres and increasing the wave-length of the receiver as before. In fact, there is hardly any limit to the number of calibrations we can make. Every one of them is, however, dependent on the accuracy of the original 900 metres calibration signal and so, in order to check this and to correct any errors of experiment, it is advisable to refer to all the other available calibration waves and to the "URSI" signals.

After what has already been said, the chief methods of using the calibrated wave-meter will be sufficiently obvious. In all cases where it is used in connection with a receiving set the telephone terminals of the wave-meter are short-circuited, but if it is used to check the transmission of an experimental transmitter the telephones are included in the circuit and the instrument then becomes a simple autodyne receiver of which the coils act as little frame aerials.

The wave-meter is very useful for receiving on the very long wave-lengths. In the ordinary way the receiver is detuned in order to give a beat-note with the incoming signals of, say, 1,000 per second. On long wave-lengths this detuning represents a very serious loss of efficiency and if the aerial circuit is tuned to exact resonance the beats may be produced by the wave-meter and greatly increased signal strength and selectivity are the results.

So far we have considered how the wave-meter may be used in conjunction with oscillating circuits, we must now consider how it may measure the wave-length to which, say, a crystal set is tuned. The wave-meter, to which a pair of telephones is connected, is placed near to the crystal set and its condenser is rotated. As the emitted wave-length approaches that to which the crystal set is tuned the latter is suddenly forced into resonance and, because it commences to take energy from the wave-meter, a loud "click" is heard in the telephones connected to the latter. After the wave-meter condenser has been rotated past the point of resonance a time comes when the crystal circuit suddenly breaks away from the control of the wave-meter and a second click is heard. If the two clicks are far apart on the condenser scale the distance between the two instruments should be increased. The clicks will then become fainter but nearer together and half-way between the positions at which they occur is the wave-length of the crystal set.

The above remarks are intended merely as an introduction to the subject of wave-meters, but enough has been said to show that every experimenter would be well repaid for the cost and trouble of making one or both of the types described.

Amateur Radio Work in Holland.

By J. WESTERHOUD.

Perhaps one of the most interesting features of experimental work is the examination of methods and practice other than our own. One of our Dutch representatives gives below a summary of amateur work in Holland, and readers will no doubt find many new ideas and circuits.

WE can divide the amateurs here, just as everywhere else, into the real experimenters and the broadcast listeners, the number of whom is greatly on the increase, especially since the foundation of the English and French broadcast stations. The real amateurs, however, do all they can to get as much as possible out of their sets, and they are always at work trying new circuits and endeavouring to solve the various problems that present themselves. The Dutch amateur is second to none of his colleagues in other countries as regards the work he does and the results obtained, notwithstanding the Dutch Government impeding his growth in no mean degree.

Receivers.

The most usual aerial here is decidedly the twin wire. Formerly this was made as long as possible, as we were not tied down to a prescribed length. But now the amateurs have realised that with short aerials fine results are to be obtained. Sometimes the cage antenna, with five or six wires, is used here, but generally only where, owing to local conditions, they must make the most of the length available.

For receiving, most Dutch amateurs use the common honeycomb-coil receiver, while for short waves the same set is used, but with spider-web coils. However, to keep the same receiver intact, a kind of double variocoupler is also often applied, which is put in the honeycomb coil holder instead of the honeycomb coils. The primary coil has thirty-five turns of 0·35 mm. wire, on a 4·5-cm. size coil; the secondary has thirty-two turns of 0·7 mm. size on a coil of 7 cm.; and the reaction coil, same as primary coil, with forty-five turns of the same wire.

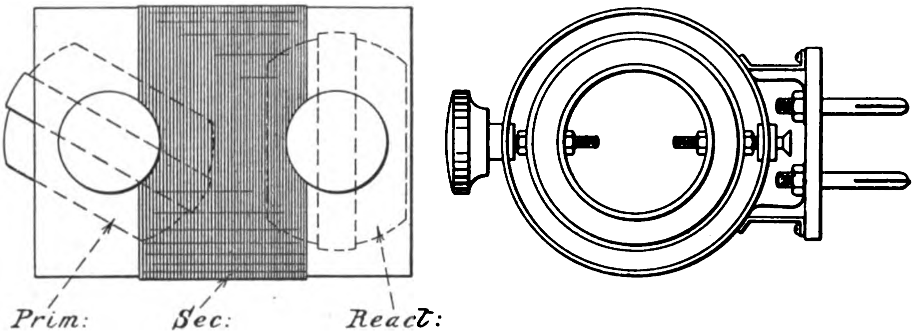


Fig. 1.—A loose-coupled tuner with reaction is too well known to call for comment, but the arrangement as a plug-in unit is certainly novel.

During the Transatlantic tests several amateurs got fine results with it, because it works in an exceptionally sensitive manner at a wave-length of 150-250 metres.

For receiving, the "Philips'" radio-valves are used; likewise the German "Telefunken" valves. Much German material is used by Dutch amateurs, so a Dutch receiver is composed of 80 per cent. German material, made of the German army stocks. Parts of receivers, transmitters and valves are very cheap here; some English amateurs who paid us a visit last Easter can bear us out in this.

To obtain one-valve high-frequency amplification in a simple manner the circuit

shown in Fig. 3 is often used by us. The coil 1 is the aerial inductance, coil 2 the secondary, and coil 3 the reaction coil.

Before the detector the high-frequency amplifying valve is placed, which is connected with grid and filament to the antenna condenser. By application of high-frequency amplifying coil 3 can be taken out, or a honeycomb coil with a few turns can be

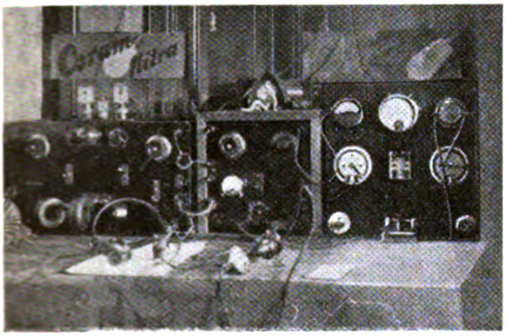


Fig. 2.—The receiver and transmitter of 0OX installed on a houseboat.

put in the place of it. When the first valve is taken out the set works again as a common honeycomb coil receiver. The high-frequency amplification obtained with it is strong. This circuit is used by us to receive the British broadcast stations. Before the establishment of the broadcast stations the amateurs had to rely more on long waves, and they applied themselves especially to amplifying the signals of weak long-distance stations. For this the note magnifier of Dr. Koomans is used with success, which is switched between a low-frequency amplifier and the receiver, so that they form together a note magnifier. Especially for weak stations and much jamming this apparatus is of great use, and is employed by us when listening to our Indian stations, such as Malabar and others.

This circuit is used to obtain selective reception. To the 'phone connection of the receiver is first connected a tuned circuit L1 C1, in which the coil L1 and the condenser C1 are so great that the circuit has an audible frequency, and will be tuned preferably to a frequency of 1,000, corresponding to a wave-length of 300,000 metres. This we get, for example, with a condenser of 0·01 mfd. and a coil of 2·5 henries. The reaction coil L2 must be of sufficient size to make the system oscillate. The heterodyne beat note of the desired signals is adjusted so as to be the same as the tone frequency of the circuit L1 C1. The reaction coil L2 is now adjusted so that the circuit is just on the point of oscillation, and therefore rectified oscillations, due to the desired signals, will be more strongly amplified than others, since the circuit L1 C1 L2 forms a critically-tuned reaction rejector circuit. L1 has 1,350 turns of 0·55 mm. size wire, wound on a coil of 10 cm. size and 5 cm. length. Coil L2 is wound on a tube of 2 cm. size and 5 cm. long, wound to an outside diameter of 6 cm. with wire 0·4 mm. size. Condenser C is a variable of 0·0005—0·003 mfd.

For receiving, the four electrode-valve is also used by many amateurs. These valves have the advantage of possessing a high vacuum, and by this a perfectly constant behaviour, while they require very little plate tension. In this respect they are even superior to low-vacuum valves. For the Dutch "Heussen" four-electrode valve a plate tension of 8—12 volts is sufficient. The common detector circuit is shown in Fig. 5. The so-called extra grid is branched off from the high tension. The strength of signals using these valves is the same as the three-electrode valves. The advantages is the low plate tension they require.

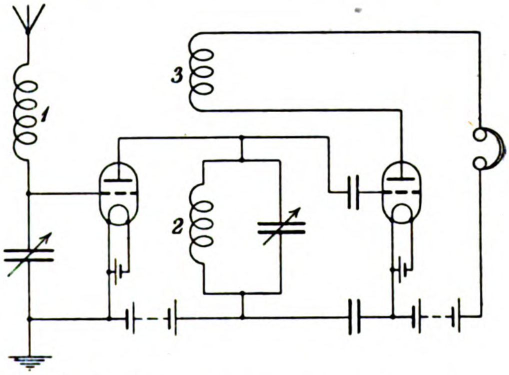


Fig. 3.—Potentials are taken across the tuning condenser. The detector valve being soft requires no grid leak.

During the Transatlantic tests of 1921 the Dutch amateurs had little success, but, encouraged by the success which some English amateurs had already that winter, they exerted themselves to the utmost to get better results in 1922, in which they

accordingly succeeded. The whole week our amateurs listened during the night, and had the satisfaction to be able to note the calls of several American stations. We had very much trouble at the time, owing to the known fading effect.

As for the receiving of the English broadcast stations, it may be said that these

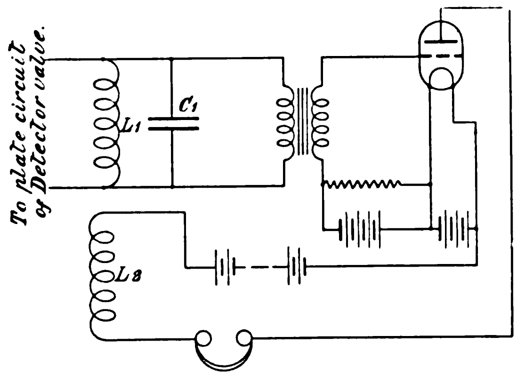


Fig. 4.—The circuit L1 C1 L2 forms a reaction rejector circuit across the intervalve transformer, and serves to reduce jamming.

stations are received very well by most amateurs here. With one valve as detector, and using one or two valves as high-frequency amplifiers, speech and music are very good. Regarding the quality of speech and music we have nothing but praise, everything being received very clearly, and it is a pleasure for us to listen for the British wireless orchestras. Sometimes we have trouble here by fading when receiving 2LO, while this is seldom noticed with the Newcastle station. We do not listen often for the French and German broadcast stations, because we have much jamming by private telegraph stations on this wave. It is likewise a great pity that the music of 2LO is sometimes jammed by ships on the wave-length of 400 metres.

Our broadcasting is still in embryo and far from perfect. For a long time we have been able to listen to music and speech from PCGG (the Hague), but it is difficult to receive the music clearly and without any disturbing sounds. Perhaps the listeners of *The Daily Mail* concerts which used to be given have noticed this already. The percentage of modulation of PCGG is great, but when the purity suffers by it a smaller and clearer modulation is preferable. Of late tests have been made by the Ned. Sein toestellenfabriek, Hilversum, in that direction, to obtain a pure transfer of speech and music. There are intentions here to start a Dutch broadcast company. A meeting of the principal Dutch radio firms has been held already in order to come to an arrangement.

Transmitters.

There are several amateurs here who apply themselves to transmitting tests, and it seems to be so much more tempting for us because it is prohibited to have one part of a transmitter at home. The severest fines are imposed if we are caught, and yet, in spite of that, there come more and more amateurs in the air. Especially on the short waves of 150—250 metres Holland has most representatives. The "nought" stations

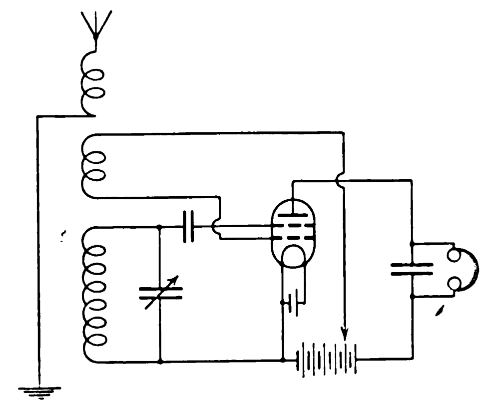


Fig. 5.—The four-electrode valve circuit shown above is used by many Dutch experimenters.

are known by most English amateurs. We have placed the "nought" before our call because we would not enter into conflict with transmitting stations in other countries which also have a figure before their call. In that manner we took the nought, knowing for sure that this figure was not in use anywhere at that time; everybody hearing our call understood that we were not officially classified. We have repeatedly asked our Government for their consent, but we have always received a refusal from our Minister, who, we maintain, is wrongly informed by his officials. After this introduction concerning our oppressed transmitting experimenters, a description will be given of the transmitters most in use, with which very good results are obtained.

The circuit of Fig. 6 is used by the station oMX, and gives very fine results. Other circuits have been tried, but this circuit was always found to be the best. The inductance C is wound on a 15-cm. size tube, with forty to fifty turns of 3-mm. size bare copper wire. To every other turn pieces of copper of the same size are soldered for taps and connections made by means of clips. The condenser across the inductance is 0·001 mfd., double spaced variable, because the whole of the high tension is on it. The grid condenser is a variable Murdock of 0·0005 mfd. To regulate the modulation this variable grid condenser is indispensable. The grid-leak is a variable of 10,000 ohms. For C.W. transmission the modulation transformer is used as a leak. The modulation transformer consists of four to five layers of 0·7-mm. size copper wire on the primary, and 10,000 turns of 0·1-mm. copper wire on the secondary. The filament of the transmitting valve is lighted by a step-down transformer. Most transmitting valves used here are the "Telefunken," 20 watts. The lighting transformer has a secondary voltage of 12 volts,

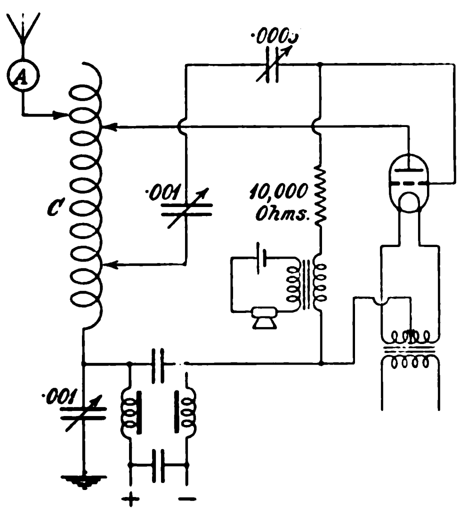


Fig. 6.—The circuit of oMX. The ·001 condenser should be between the grid condenser and filament.

and a tap is brought out from the centre of this winding. Two meters are used, aerial ammeter and a plate milliammeter. The filter circuit is made of the usual condensers of 2 mfd. and inductances. The high tension of 1,250 volts is obtained from a separate transformer, from which the alternating current is rectified by two "Philips'" rectifier valves. With this transmitter, and using a 20-watt transmitting valve, an aerial current is obtained of about 1·3 amps., using a cage antenna of five wires 24 metres long and 18 metres high.

All is done to obtain a fine pure note, as it is proved more and more that only with a pure note are great distances to be reached.

Fig. 7.—A general view of oMX, who is well known to many British experimenters.

In the photograph we see the receiver-transmitter of oMX (formerly PÉ). The left half of the set is the transmitter and the right half the receiver. As a receiver the honeycomb coil circuit is also used here, with variable grid condenser and a switch for series-parallel of the primary condenser. The transmitter consists of a variable grid condenser, a variable condenser across the inductance, and a switch for the different taps on the inductance. In the middle of the set are the ammeter and the plate milliammeter. With this set excellent work is done with the key and with 'phone. At full power, with 1·3 amps. in the aerial, the signals were heard QSA by several English and French listeners. One night 2JF and 2ZS at Liverpool reported the speech and music of this station all over the room.

With the coming Transatlantic tests it will be tried, by putting transmitting valves in parallel, to obtain a greater energy, hoping to reach the Americans with this.

Another circuit used here by the stations oDV, oAA, oNY and others is shown in Fig. 8. The peculiarity of this circuit is that, using it with a long aerial, the short wave of 200 metres is to be reached as well,

though, of course, not with such profit as with a specially made aerial for short waves. For the coils 1, 2 and 3 common spider-web coils are used, with an inside size of 8 cm. and a wire size of 1 mm². The antenna coil 1 and coil 3 have seven to ten turns, and the grid coil has ten to fifteen turns. The antenna current obtained with this circuit and a 20-watt transmitting valve is about 1·2 amps. As a telephony system the common 'phone transformer is generally used by us, as shown in the circuit of oMX. This system is easy to handle. The system of PCGG is also used here by some amateurs, as shown in the circuit of oDV. Across the microphone is a variable shunt. It is difficult with this system to find the exact shunt, and likewise the exact resistance, of the microphone. With the circuit of oDV, also, very good results are obtained, but it is not so easy to handle as that of oMX.

Last winter the Dutch amateurs began, for the first time, with tests on the short wave, and they immediately met with success, both with transmitting and receiving English and French amateurs. The English stations 2KF, 2OD, 2NM, 2KO, 2JF and 5MS were heard here last winter the strongest of all. Of the French amateurs the stations 8BM and 8AB were strongest, but with a bad note, and, owing to this, very difficult to tune.

Excellent work is done by oMX on several Sunday mornings from 2 till 4 o'clock. As

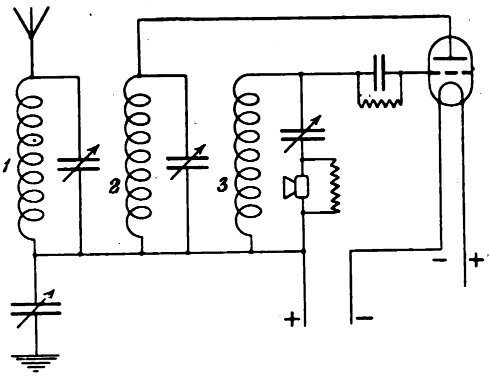


Fig. 8.—A peculiar circuit used by several Dutch stations. The grid circuit is connected to the positive high tension, a high value leak being employed. Note the system of modulation.

it is very quiet in the air at this time it is possible to work with several English stations which have 0·25 amp. and even less in aerial. In this manner he worked with English 5WR, who had 150-volt dry cells on the plate and 0·1 amp. in the aerial. The signals of this station were audible with one valve, though very bad fading impeded the reception. In the same manner 5LZ and others worked with oMX, several with 0·25 to 0·35 amp. in the aerial. The signals were received here very distinctly with one valve on the common honeycomb coil receiver.

Up to this moment we have had connections with thirty-two English transmitting stations and with four French stations, and we hope to double the number this winter.

Detecting the Presence of Oscillations.

When experimenting it is frequently desirable to find if oscillations are being generated in a circuit. Probably the most convenient method is the finger test. The finger is placed on the grid of the valve connected with the circuit to be examined and the nature of the click produced in the telephones indicates the condition of the circuit. The appended table summarising the results is due to J. H. Morecroft.

Nature of Circuit.	Finger on Grid.	Finger Removed.
No Grid Condenser, no Oscillations	No click.	No click.
,, ,, Oscillations	Click.	Click.
Grid Condenser, no Oscillations	Click.	Probable click.
,, ,, Oscillations	Click.	Click.

London's Experimental Ether.

By THE CRITIC.

FROM time to time notes have appeared in the popular wireless Press concerning the various amateur transmitting stations. These remarks have dealt in the main with stations working on 440 metres, special mention being made of various people's telephony and gramophone records. It is not surprising that many now taking up radio on hearing the usual 440 metres babble after broadcasting and reading such notes as I have mentioned, say that all this amateur transmission is all very well and interesting to those concerned, but what good does it do to anybody ? Music can be transmitted far better than they do it, and they appear to spend their time asking " How do I come in now ? " Unfortunately this is quite true. There is undoubtedly a large number of transmitting stations now working who do no real experimental work of any value, and just fill the overcrowded ether with ghastly reproductions of ancient and hoary gramophone records. But, on the other hand, there are quite a number of experimenters carrying out tests of real scientific value on the shorter wavelengths, from 150 to 200 metres.

In these notes I propose to mention a few of those who can be picked up very often in the evenings. These examples will show that there are some who are justified in having licences, and, perhaps, it may tempt some of the 440-workers to descend to the " QRM-less " region of 200 metres. Incidentally, it may be mentioned that 200-metres work can be carried out during broadcasting hours without interference to any " receiver " in the vicinity worthy of the name.

Possibly the best example of what a real experimenter can do is 2OS. His signals are not overstrong, as he is 25 miles out, but I heard him say that his transmitter was putting ·02 amp. into the aerial when he was not speaking and ·8 amp. on speech. This in itself is excellent " quiescent aerial " work, and more especially when the fine speech quality is noticed, but his transmitting valves cost 3s. 6d. each—he uses ordinary "Osglim" neon tubes throughout ! This is surely an achievement. 2OD and 2OS sometimes work excellent duplex also ; the speech of the former station is of marvellous quality and purity. His C.W. also seems to pierce a long way—he can be heard working 8AB of Nice, over 600 miles away, quite often.

2NM, 2KF, and 2DF, among others, can also be heard late at night working over very long distances, and doing very interesting work. 2SH's well-known 500-cycle A.C. disappeared recently, and soon after a weak voice was heard using a couple of receiving valves. Rather a come-down in the world. I heard him working over 25 miles not long ago, using a single R valve, 4 volts on filament, 240 on plate, and ·4 amp. in a 4-ft. indoor frame aerial. Signals were reported R4 ! 5GF also can be heard on a loop sometimes. He works to Epsom on it quite often. 2VW is one who never has the same things up two days running—he seems to be doing " indoor " work at present. Last time I heard him he was complaining bitterly about Mullard's glass. He said he was trying some special stunts with filamentless valves, and had been round to 2SH pinching burnt-out bottles from him. When he tried them he found Mullard's glass wouldn't mix well with what he wanted to seal on to it ! He'd better write and ask them to change their glass ! 2TA, who gets such good aerial current and ranges, using only 240 volts on the plates of a battery of valves in parallel (·9 on 10 watts), " packed up " his counterpoise the other day, as the household couldn't walk across the garden. Last time he was on he complained bitterly that since this his aerial resistance had risen to four times its previous value. He gave it up and went to Switzerland to look for the lost amps. !

There are, of course, many other stations working on the short waves doing really interesting true experimental work, and I recommend anyone who has not done so to get his receiver down to short waves for something really interesting to listen to.

Radio Station 2TA.

Amateur transmission stations usually show a marked dissimilarity in circuits, systems, and apparatus employed. This is due no doubt to the fact that many experimenters build their sets as a result of their own investigations. In order that experimenters may become acquainted with the work of others, details of stations embodying novel methods and circuits would be welcomed in these pages.

THIS station is situated on the top of Highgate Hill in the north of London. The antenna system consists of a twin flat-top cage aerial and a counterpoise. The cages of the aerial are of six wires, each on 1-ft. 6-in. hoops, and are supported on spreaders 11 ft. apart. The height of the aerial is 50 ft. at the distant end (a tree) and 60 ft. at the lead-in. The counterpoise consists of twelve wires in fan formation underneath the aerial, with a caged lead-in to the house. A general view of the receiver and transmitter is shown in Fig. 1. The receiver consists of one H.F. detector and one L.F., mounted on panels, with separate condenser and tuner panels. Although mounted up in a box this receiver can be dismantled in quite a short time, each unit taking apart, so that variations of circuit can easily be made.

A better view of the transmitter can be seen in Fig. 2. This transmitter is essentially of the experimental type, and many circuits were tried before the final one was adopted.

The circuit is a modification of the standard Colpitts, and is shown in Fig. 3. This circuit can be very strongly recommended, and is, in the opinion of the author, much the simplest and most efficient for 200-metre work. Only one tuning inductance is necessary, with three clips. The aerial ammeter (0—1·5 amps.) is mounted on the top of the

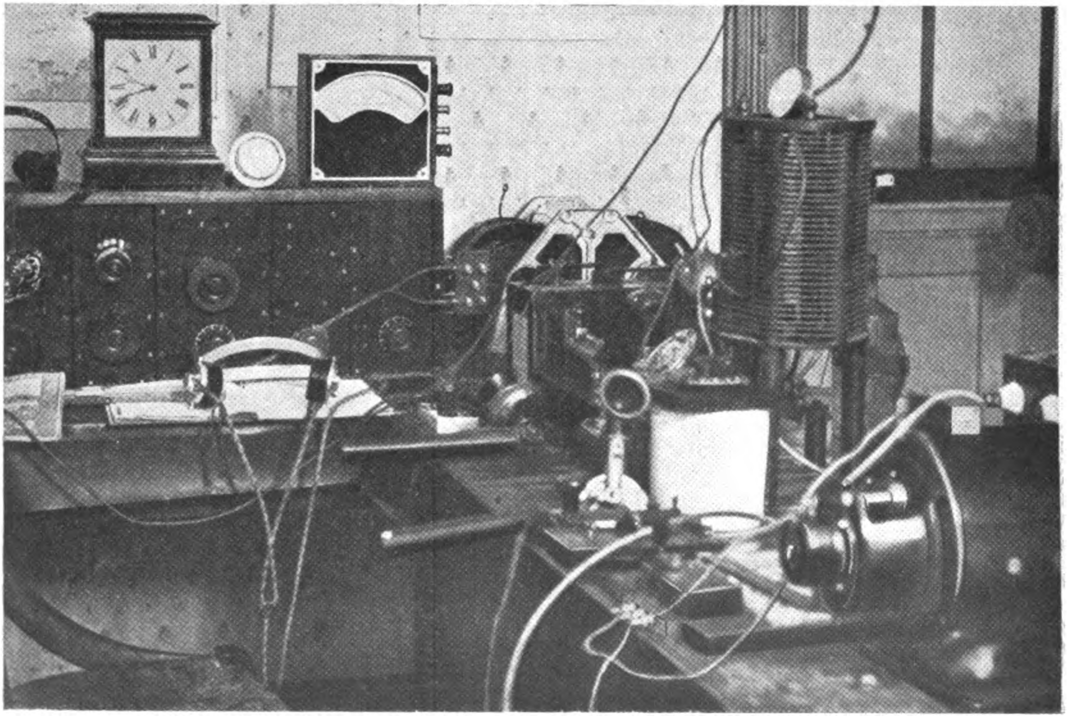


Fig. 1.—A general view of the receiver and transmitter. The receiver, although built on the panel system, can be quickly dismantled for experimental purposes.

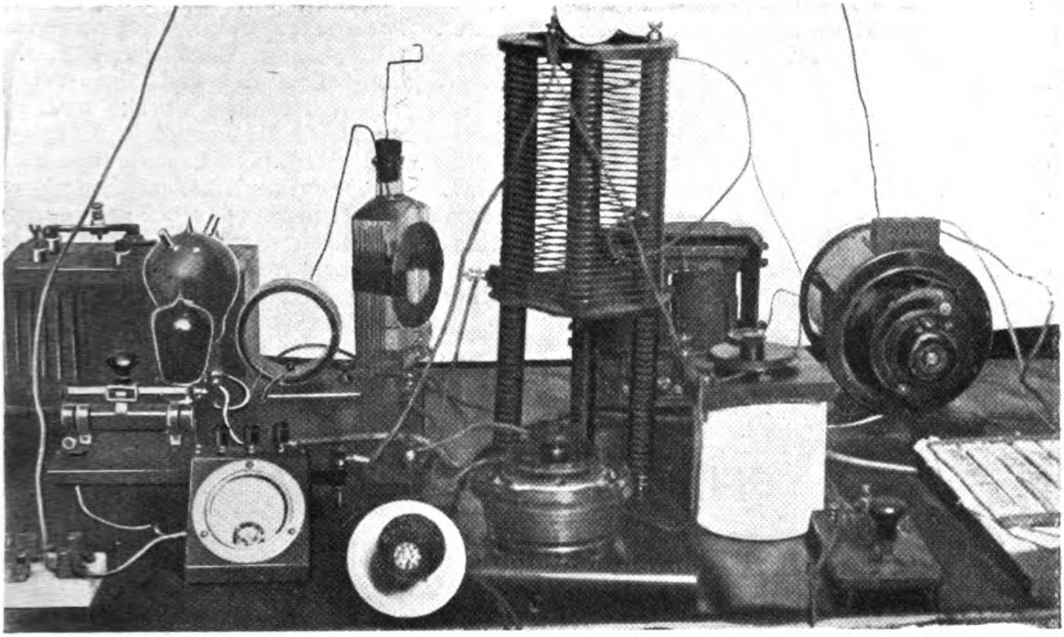


Fig. 2.—It will be seen that the transmitter is essentially of the experimental type. Note the water grid leak with the choke tied to the side of the bottle.

helix, the antenna clip being the centre one. At the back may be seen the anode-feed radio-frequency choke and the variable water grid-leak. One important point in this circuit is the inclusion of an H.F. choke in series with the grid-leak, or by the ordinary choke-control method.

Two methods of H.T. supply are available either from the 240 volt D.C. mains or from a rotary converter, seen on the right in Fig. 2.

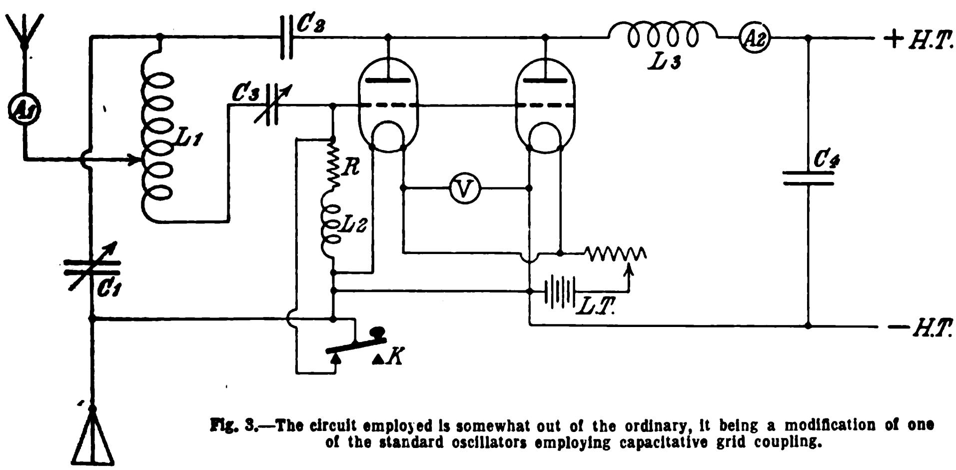


Fig. 3.—The circuit employed is somewhat out of the ordinary, it being a modification of one of the standard oscillators employing capacitative grid coupling.

in the grid-leak circuit. This makes an enormous difference to the efficiency of the circuit. Modulation is obtained either by the inclusion of a microphone transformer Since the photo was taken, an H.T. step up transformer has been installed for using a 48 jar chemical rectifier, a very satisfactory D.C. supply at 1,500 volts has been obtained.

This method is not always used, as a high H.T. voltage and low anode circuit are found to be much more efficient. A filter system has, of course, to be used for phone. Keying is done by short-circuiting the grid-leak and choke, as this method seems to cause the least disturbance in the neighbourhood.

As regards the efficiency of this station with slightly lower aerial, the best radiation obtained has been ·9 amp. with 10 watts input. This was done using a French transmitting valve and a Mullard "A" valve in parallel, with 240 D.C. on the plates. The greatest transmitting range has been to oMX, about 280 miles. On the receiving side the author finds three valves quite sufficient for most work; with an acceptor circuit all the broadcasting stations can be heard while 2LO is in action five miles away. For distant work an Armstrong super heterodyne set is being installed. In conclusion, the author would much appreciate cards and reports from any station hearing either C.W. or speech from this station.

H. ANDREWES.

The Month's "DX."

Recorded by HUGH N. RYAN (5BV).

The increasing efficiency of amateur transmitters and receivers is resulting in the creation of many new long-distance records which are undoubtedly worthy of mention. It is proposed to record month by month work in this direcion, and the Editor will be pleased to receive details for inclusion in these pages.

MANY of the keenest and most able of our transmitting experimenters devote their efforts entirely to DX work, or the covering of the greatest possible distances with their transmitters. There are many others who, while spending some of their time on shorter-range telephony and kindred work, also carry out DX when they consider conditions to be favourable. It is, I think, generally felt by both classes of experimenter that DX has not received the attention it deserves in radio periodicals. One hears a great deal about the telephony men whose gramophone records are heard in remote parts of our islands. Most of us are kept fully aware of our musical neighbours who strike up with their ± ten watts, without previously listening in, pump out a series of records, and switch off without subsequently listening in for the report we should so much like to give them.

But the DX station does his work chiefly in the small hours, and is generally an obscure sort of individual. The worst of it is that he is generally despised by the lordly telephony men, who regard him as a reactionary who is still dabbling with the departing relics of an obsolete system. Some of our newest telephony stations are even displaying a lamentable difficulty in understanding the "obsolete" code used.

As yet, the DX man has only come into his own for a brief period yearly, when he burns the midnight amps in his efforts to receive Americans on the fewest possible valves, and the gramophone men wonder how he does it.

But the best DX stations are working all the year, and these notes are an attempt to chronicle, month by month, the results they are obtaining.

At present, very little European DX is in progress. Everybody seems to be spending the day-time in building that transmitter which the Yanks simply can't help hearing, and the night in teaching the receiver to catch the Yanks' replies. One or two stations are already making their initial attempts to get across. The best I have heard yet is 2JF, who seems to be in the fore of most good things in DX. 2KW, a confirmed optimist, has been heard to call at least one Yank with 0.1 in the aerial. The London contingent appears to consist, so far, of 5NN, 2SZ, 2SH and 5BV. I am afraid that none of the latter is in form yet, judging from the reports I have received from the North. Quite a number of stations

have started work on the receiving side. The two most striking features of reception so far are the great number of Americans who are received considering the time of year, and the great number of stations who are confining their attentions to single-valve receivers. 5 NN has been doing very well with a Reinartz. 2ZS of Liverpool tells me that he has logged about 70 Americans this month on one valve. By the way, 2ZS's signals come in remarkably well in London considering his aerial current is only 0.12. My own log is about 35 so far this season, on one valve. Our old American friends of last year seem conspicuous by their absence. 2FP and 1BCG are very strong, as usual, and I have had one report of 2EL, but what has happened to all last year's favourites, 1XM, 1BD1, 2BML, and 8AQO ? Has anyone heard them ? I think that very few of the best Americans are working at present, as although we hear so many American amateurs, we seem to hear a different batch every time. With the exception of 2FP and 4FT, I have never heard any of them on two different nights. Perhaps the best of them are giving their transmitters a rest while they are busy improving their reception. They certainly were not at all pleased with their results last year, and intend doing much better this time. We hear a lot of complaints from our men that we can never get over while the Americans use such inefficient receivers. There is no need to be so pessimistic. I cannot believe that there are really no first-class receivers over there. Our transmission leaves much to be desired at present, and it is up to us to improve it.

You have no doubt noticed how very quiet the French stations are now. It seems likely that they are preparing their transmitters for the winter's work. They are allowed 100 watts in the aerial, and, as very few of them use anything like this power, they have plenty of room for increasing this factor in their transmissions. 8AB will probably use the same power as last year. Certainly he is strong enough to carry anywhere. 8AQ tells me that he is installing a 350 cycle alternator to replace his present 50 cycle supply. He hopes to increase his power considerably, and also to improve his note. Dr. Corret of 8AE and 8AW is using notepaper headed " Comité des essais transatlantiques," which is a good sign, though I do not know quite what he proposes to do. 8BV seems very keen on American work. 2ZS has been heard loudly on one valve by 8BF, when using two watts. There is no doubt about the efficiency of some of the low-power stations in the North.

I do not know what the Dutch stations are doing this year, but the strength of PCII has greatly increased recently ; I believe he has about 6 amps. in the aerial.

Those who stay up in the small hours have probably noticed how well the American broadcasting stations are coming in now. WGY and KDKA are exceptionally good, and on a good night WGY is comfortably readable on one valve. 5NN has been getting good loud-speaker results on three valves.

This month's notes have been necessarily confined to a few stations, as only a few are working DX at present. During the coming month, given favourable weather, things should become much more lively. I try to keep in touch with all that is happening in DX, but it is impossible to hear everything. This may perhaps be a blessing in disguise at times, but if any stations get any very good results on DX transmission or reception, we shall be very glad to hear about them. In America they publish a monthly list, known as the " Brass Pounders League," of the stations who have handled the most messages during the month. Fortunately message-passing does not enter our work, but it would be interesting to know who receives the most American stations each month. The best log I have heard of this month is 70 different stations, received by 2ZS. This record will, we hope, be beaten many times in the coming month, and may it be on single valve sets.

A Primary Cell H.T. Battery.

By N. K. JACKSON.

Experimenters are apt to overlook the necessity for an anode battery which is capable of supplying a considerable discharge current for many hours without tending to polarise. Multi-valve receivers employing power amplifiers soon exhaust the conventional high-tension battery, and one very practical solution of the difficulty is found in the small Leclanché cell. Below, the author has developed the necessary details for a suitable battery for general purposes.

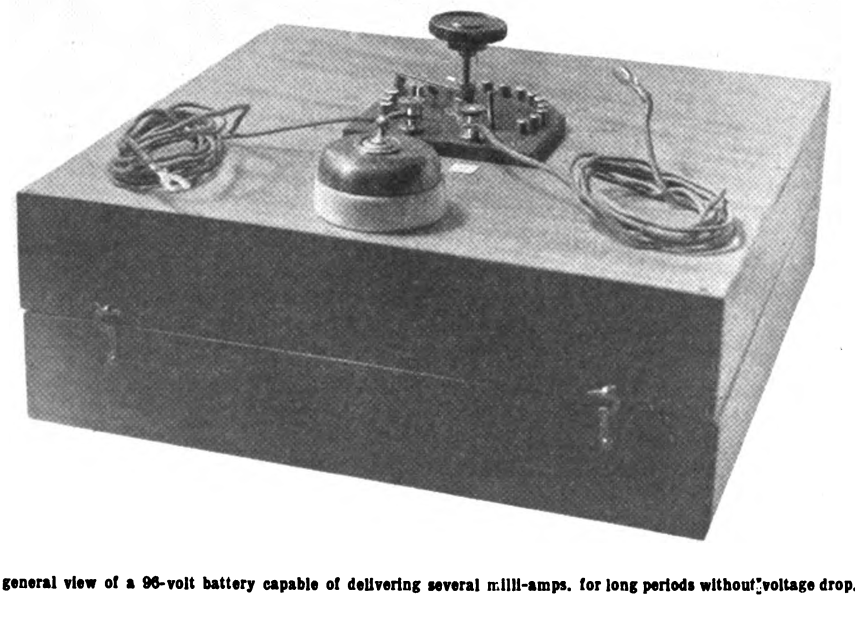
THE problem of the maintenance of the high-tension battery is one which every radio enthusiast sooner or later comes up against; one hears continuous complaints of trouble experienced, and of frequent need for new batteries, or of the considerable drop in voltage after use for a quite short time.

With the idea of solving this problem the writer constructed his H.T. battery from primary cells—in this case, the small sac filling with a solution of sal-ammoniac and water.

It will be seen from the photographs and drawings that the cells are arranged in a flat box, with the switches, terminals, and leads mounted on the lid.

The arrangement of the cells was such as to give 12 volts at each "live" stud of the rotary switch, with a total voltage of 96.

As each cell is assumed to give 1·5 volts, this means a total of 64 cells, which are all



A general view of a 96-volt battery capable of delivering several milli-amps. for long periods without voltage drop.

Leclanché cells now on the market, as shown in Fig. 1, and these seem to give excellent service. As will be seen from the figure, these cells consist of a small glass jar, a zinc plate with connecting wire, and a positive sac element, and the top is sealed with a disc of cork-like substance; they are charged by connected in series, *i.e.*, negative to positive, right through the whole 64 cells, and tappings were taken off and connected to one of the studs of switch at every eight cells, so giving 12 volts at each tapping.

Of course, any number of cells may be used to total the voltage required.

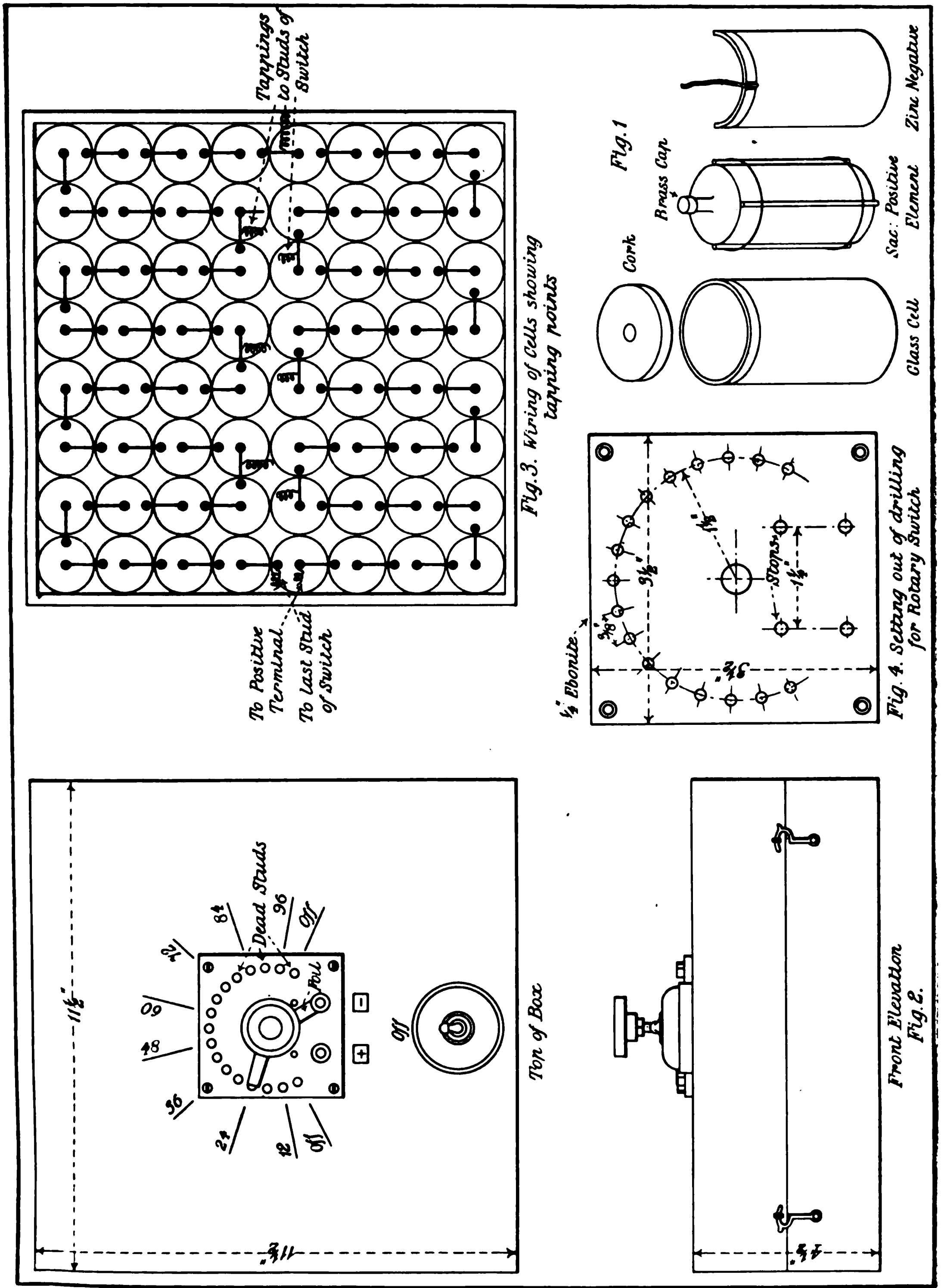


Fig. 1

Fig. 2. Front Elevation

Fig. 3. Wiring of Cells showing tapping points

Fig. 4. Setting out of drilling for Rotary Switch

A tumbler switch was put in the positive lead to enable the battery to be switched off without altering the position of the rotary switch.

The various voltages can be marked on the lid in black ink and varnished.

The box was constructed of ½" mahogany to the dimensions given in Fig. 2, hinges and hooks and eyes for fastening being fitted, and the whole varnished or polished; a hole was cut in the lid to clear all the studs and terminals in the rotary switch, which was mounted on ½" ebonite, and was made up from standard parts, consisting of switch arm and knob and contact studs, a point to be remembered being that between every "live" stud to which a tapping from cells is connected, a "dead" stud must be put in.

The ½" ebonite is to be dressed up square on edges and to the dimensions given in Fig. 4, and set out and drilled for studs, terminals, switch arm spindle, and fastening screws.

The switch arm should move smoothly over the whole of the studs; see that these are all of the same height, as they sometimes vary.

A stop-pin is screwed in at each end of the travel of switch, and a piece of brass foil is used under the switch arm to connect between it and the negative terminal.

The complete switch is now to be screwed down in opening in lid, with brass counter-sunk screws.

A tumbler switch is screwed to lid of the box as shown, and a lead taken from the underside of the positive terminal, and connected to the switch, and from the switch back to the positive element at starting cell in the battery.

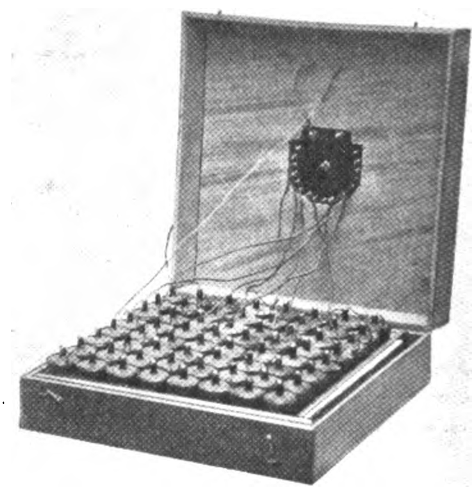
Two leads are made up of single flex, for connection to the radio set, and will be seen coiled on the lid of box in the photograph.

Before fitting cells into the containing box they are to be filled with sal ammoniac and water in the proportion of 4 ozs. of sal-ammoniac to 1 pint of water; allow the sediment to settle after mixing the solution.

Let the sac element stand in the solution in glass cell without cork or zinc, for eight hours, then carefully insert zinc element, which is in the form of a bent plate, and put in the cork, which has a hole in the centre through which protrudes the end of the sac element, nipping the connecting wire from zinc between the cork and glass jar.

Carefully wipe away any spilt solution, and seal the tops of the cells with hot paraffin wax by means of a camel-hair brush.

Scrape the ends of connecting wire from the zincs of all cells which are coated with black enamel, and clean and tin the brass caps of positives, ready for soldering.



The internal arrangement of the battery facilitates easy inspection and permits any cell to be examined individually.

The cells may now be assembled in the box and connected in series, as shown at Fig. 3.

Solder each connecting wire from zinc (negative) to the brass cap of next positive element, in the direction shown in Fig. 3; this is to be continued right through the whole of the cells, and will leave one positive element and one negative element unconnected.

The positive is to be connected to the tumbler switch as before mentioned, and so to the positive terminal, the negative being connected to the last stud of rotary switch.

For tappings single flex was used, stripped of its outer silk covering, leaving the rubber insulation intact, the two ends being bared and soldered to stud and tapping point of battery respectively.

The construction of the battery has proved time well spent, and can be confidently recommended to anyone who has had trouble with the ordinary dry cell type of H.T. battery.

The Patent Aspect of Experimental Work.

When the experimenter invents a new circuit or develops a new principle, his first thought is to protect the idea, but he is very frequently at a loss to know how best to approach the subject. Further, it may not always be desirable to patent an idea, and the pros and cons and methods of procedure are carefully discussed below.

WHEN one spends a good deal of time experimenting one is apt to get ideas and inspirations about things which might be of commercial value if only they were pursued on the right lines. Discoveries and inventions not only attend well-organised experiments made with some definite end in view, but are frequently the result of dabbling with things at random. Moreover, ideas have a disconcerting way of occurring unexpectedly at all sorts of odd times and places, such as when one is in bed, on a 'bus, or even in one's bath.

No matter how trivial an invention may seem, it may be worth patenting, provided that :—(1) It really will work ; (2) that it is new and not anticipated by someone else. Large companies with plenty of capital patent all their ideas and most of those which occur to their employees. With the individual inventor acting on his own behalf, a patent is more or less of a speculation. It costs him about £5 to get Letters of Patent granted him for his invention, and if he makes use of the services of a patent agent there is also the agent's fee to consider. He may be able to sell the rights of working the invention for a very profitable figure, or license the rights of working on a royalty basis, or the invention may prove an unsaleable "dud." A valid patent gives the owner or owners a monopoly of the invention concerned throughout this country for a period of 16 years, provided that the requisite fees are paid at stipulated periods. After the expiration of this period the invention becomes public property and anybody may work it commercially for profit. Thus, after 1930 most of the basic thermionic valve patents will have expired, and anyone will be able to manufacture valves at competitive prices without being prevented from doing so.

Anyone may use a patented invention experimentally for the purpose of improving or modifying the invention where no profit is involved.

The patent laws are principally intended to enable an inventor to derive the first commercial benefits of his invention, and to prevent the fruits of his own genius or labours being unfairly exploited by other parties. At the same time the legislation has the object of encouraging home industries and protecting the public interests. The rights which a patent confers are not intended to enable the patentee to withhold his invention from the market, or to market it at any exorbitant price he likes ; in a word, the patent laws do not comprise a profiteer's charter. If it is considered that a patentee is using his rights in a way contrary to the public interest, refuses to license rights of working to other parties, or demands unreasonable prices for such rights, then appeal may be made to the Comptroller at the Patent Office by any parties interested in the matter. This aspect of patent law seems frequently to be lost sight of by the public.

What can be Patented.

Any new method of manufacture, chemical process, modified mechanism, manner of working something or production of some effect is patentable, provided that it is of a concrete and not abstract nature. Written matter, sequences of words, music or artistic designs cannot be patented, but come under the respective headings of Copyright and Designs. The Patents Rules state that nothing which is contrary to law or morality can be patented. The latter aspect does not concern us here, as the highly moral nature of wireless is above question.

To be patentable an invention must be new, and the application for a patent must be made by "the first and true inventor," or if the application is made jointly by more than one person "the first and true inventor" must be one of the applicants. An invention cannot be patented once it has been :—

(1) Patented before;
(2) Sold or worked for profit;
(3) Exhibited at an exhibition recognised by the Board of Trade without notifying the Comptroller; or,
(4) Described in a foreign specification open to public inspection at the Patent Office or in a registered journal published in this country.

Thus, if you wish to patent an invention, keep as close as an oyster about it until you have filed a Provisional Application. If you do not want the trouble or expense of patenting your invention and do not want anybody else to patent it, submit a description of it to EXPERIMENTAL WIRELESS for publication.

The most valuable inventions are by no means always the most intricate ones, or ones involving much technical genius. A man may make a fortune out of a slight improvement in braces or contact studs, while the man who invents a 17-valve atmospheric eliminator may live and die obscure and poverty-stricken. Inventions dealing with improvements in details of manufacture which can only result from research or practical experience may be very paying if judiciously worked. Take, for example, the case of the American G.E.C.'s 1,000-kw. transmitting valve. The key to the construction of a valve to handle such enormous powers was the evolution of a satisfactory method of sealing metal to glass, thus making it possible to construct a valve with a metal envelope instead of a glass one. This copper-to-glass seal has probably done more for high-power wireless transmission than any other invention during the last three years, and has placed the thermionic valve on an equal footing as regards power with H.F. alternators, the arc and the timed spark.

Procedure for Obtaining a Patent.

If an inventor has not had any experience of patent work it is safest for him to act through a patent agent. This involves extra expense, of course, and if the inventor wishes to act for himself he will not find much difficulty in doing so if he pays careful attention to the Patent Rules.* The first thing he should get hold of is the pamphlet entitled "Instructions to Applicants," supplied gratis at the Patent Office on application. The officials at the Patent Office are always courteous and ready to assist by giving information when required.

It is not possible to give full details of procedure here, but the most important steps in obtaining a patent are indicated below.

Provisional Specification.

The applicant may file a Complete Specification straight away and obtain a full patent within a month or two, but this is not advisable and is seldom done. It is best to file a Provisional Specification first and draw up the Complete at leisure. In order to obtain a Provisional Patent a clear and concise description (the "Specification") of the principal involved in the invention must be written or typewritten in duplicate on foolscap-size paper (one side only), leaving a 1½-in. margin on the left-hand side of each page. Each of these descriptions must be accompanied by a Patent Form 2† filled up in the prescribed manner. The original MS. or typescript must also be accompanied by a Patent Form 1. Never pin a Patent Form 1 to a carbon copy by mistake, as this distresses the officials more than anything. Before the application can be filed the Patent Form 1 must be stamped at the Patent Office, and for this purpose the form, along with £1, must be taken to the Stamp Room and handed across the counter. The form is stamped and returned, but, of course they keep the £1. The stamped form, accompanied by the original and duplicate specifications, are now handed in at the Enquiries Department of the Patent Office, where a receipt is given bearing

*The prospective patentee will find all the information he is likely to want in the following publications on sale at the Patent Office, 25, Southampton Buildings, London, W.C.2:—"Patents and Designs Act, 1919," 3d., by post 4½d. "Patents Rules, 1920," 1s., by post 1s. 2d.; and also "Patents Simply Explained," Percival Marshall & Co., 10d. post free.

†Blank forms unstamped are supplied gratis on application at the Patent Office.

the date and number of the provisional application. A patent bears the date at which the first application was filed. All patent business at the Patent Office must be transacted between 10 a.m. and 4 p.m., so that it is no good trying to file an application before breakfast or after tea. If everything is in order the applicant will in due course (and certainly not before) receive a communication accepting his application. If the specification is returned for some error or omission to be rectified, the matter should be attended to at once and the papers returned to the Patent Office as soon as possible. The application will retain the original date of filing if no unreasonable delay is made.

A Provisional Patent protects the applicant for nine months in such a way that he can publish details of his invention, improve it, or work it for profit without sacrificing his chance of obtaining a full patent for it later. The provisional protection costs only £1, so that if the invention proves to be a failure the loss over patent expenses is not heavy. Articles manufactured under a Provisional Patent must not bear the word "Patent," but may be marked "Patent Pending" or "Patent Applied For." Damages or restraint for infringement cannot be obtained on the strength of a Provisional Patent, and even when full Letters of Patent have been granted no damages can be claimed for infringements which took place while the invention was covered only by a Provisional Patent. It is, therefore, to an inventor's advantage to file his Complete Specification as soon as possible after the Provisional, if his invention is proving marketable.

Complete Specification.

If the applicant started by filing a Provisional Specification he must file a "Complete Specification" within nine months of the first date of application, otherwise his application will be "deemed abandoned." The Complete Specification must contain a description of the invention involved, worded clearly and giving sufficient detail for anyone acquainted with the art to make or work it for himself. At the end of the Complete Specification definite claims must be made for the features of the invention which are maintained to be novel. These claims should be numbered and should be clear and concise. The subject matter of the Complete Specification should agree substantially with that of the Provisional, but it may be more detailed and reasonably extended. It is important to note that a Patent can only cover one invention. The Examiner often holds up an application on the grounds that it comprises two or more distinct inventions. Drawing should always accompany the Complete Specification where they are likely to make the description clearer. Details as to how these drawings should be prepared are given in the Patents Rules, 1920.

An original manuscript or typescript of the Complete Specification, along with the original formal drawings in black ink, must be accompanied by a Patent Form 3 duly filled in and stamped (£3 this time). This must also be accompanied by a duplicate copy of the Complete Specification and Drawings pinned to an unstamped Form 3; the lot is handed in at the Patent Office, as in the case of the Provisional Application. The Complete Specification, its copy and all sheets bearing drawings must bear the signature of the applicant; this applies to the Provisional Specification as well.

After the Complete Specification has been filed an official search is made to ascertain whether the invention claimed has been anticipated. If it has, the applicant is notified, and he will either have to modify his specification so as to clear the anticipation or he will have to abandon his application altogether. No search of this kind is made in the case of the Provisional Application, and the fact that an inventor gets his Provisional Specification accepted is no guarantee that his Complete Specification will be accepted. If the search reveals no anticipation the specification is accepted provided that all other details are in order. The complete specification must be accepted within 15 months of filing the original application, otherwise the Patent will lapse. When the Complete Specification has been accepted the applicant is notified, and in order to clinch the matter he has now to pay the Sealing Fee of £1 to have his patent "sealed." He does this by filling in a Patent Form 12, paying £1 at the Stamp Room to have it stamped and handing it in at the Enquiry Department at the Patent Office. In due course the applicant receives

his sealed "Patent," which is an artistic and highly legal-looking document, with words on it and bearing the large red seal* of His Majesty's Patent Office; a free copy of the printed specification is also enclosed.

After the sealing fee has been paid there is nothing more to be paid until the fourth year from the date of the Patent, before the end of which year £5 must be paid for the continuance of the Patent during the fifth year. Before the end of the fifth year £6 must be paid for the sixth year, and so on until the fifteenth year, when £16 must be paid in respect of the sixteenth year. After the sixteenth year the Patent expires and the invention becomes public property. It will be seen, however, that for a total of £5 a patent can be held for four years, which is quite long enough to enable the patentee to decide whether his patent is worth preserving during the remaining twelve years.

Any Patent Forms, ready stamped, may be bought not only at the Patent Office, but also at several of the more important London Post Offices, and in the chief Post Offices in most of the large provincial towns. Stamped forms must be paid for in hard cash or currency notes at the Patent Office—they won't look at a cheque. It is highly important to pay all fees promptly within the periods set forth in the Patents Rules, 1920.

Patent work has many ramifications such as foreign applications, convention dates, extension fees, opposition to grants, etc., which only concern applicants under special circumstances and cannot be dealt with here.

The Patent Office Library.

Attached to the Patent Office at 25, Southampton Buildings, is a large free library open to the public. There is a complete collection of Patent Specifications, and anyone can look up almost any invention ever patented; the public also has access to a very good collection of books and papers on every technical subject. The place is a gold-mine of information, but it is expressly stated that you must not use the place for word competitions, and you are not expected to eat your lunch there.

A great deal of useful information can be gained about wireless by the study of its patent history. The Patent Office Library reveals many interesting things that do not make their way into current publications.

The Patent Office has a Sale Branch where one may buy copies of Published Specifications, the weekly *Patent Journal*, Abridgements and other publications dealing with Patent matters.

E. H. R.

*The seal is only made of red glazed paper, but it carries authority and is appended in the right spirit.

"Experimental Wireless" Laboratory.

Mention was made in our first issue of the laboratory and free calibration service, to which we refer our readers. Other details will be found elsewhere in this number.

Our readers will, no doubt, be interested to hear that our laboratory is nearing a state of completion, if such can be said of any laboratory. Perhaps we should say that our calibration department is complete, and we are pleased to note that readers are taking full advantage of the free calibration service. A very large number of instruments has been received during the month, and we have to apologise for the slight delay which was caused by the initial flood of condensers, wavemeters, inductances and resistances which found its way to our editorial offices during the first two weeks of October.

We have to thank several manufacturers for their co-operation in the equipment of the laboratory by the supply of scientific instruments on special terms. Amongst these are Messrs. Gambrell Brothers, Messrs. Radio Instruments, Ltd., Messrs. Chloride Electrical Storage Co., Ltd., and Messrs. The Dubilier Condenser Co., Ltd., who presented us with a set of standard condensers.

Valve Receivers on D.C. Mains.

By ALEXANDER J. GAYES, M.J.Inst.E. (*late Durham Bursar*).

Although multi-valve receivers have been used by experimenters for some years, most have been content to derive their power from secondary cells. It is surprising that little has been done to utilise existing domestic supplies, which is certainly a most economical method of working. We give below full details for working from direct current mains.

IT is not unusual to find the owner of a perfectly good receiving set is unable to use it to the extent he would wish for fear of the accumulators running down. In these days of continuous nightly broadcast programmes, the drain on the batteries becomes a serious setback, particularly in the case of multi-valve circuits, where the size and weight of the accumulators render their transportation to and from the charging depot a somewhat strenuous undertaking, unless one is fortunate enough to subscribe to one of the excellent battery service schemes now in operation. Even where a lighting supply is available, the expense of charging one's own accumulators, which are often from 60 to 120 ampere hours' capacity, is very considerable, unless a transformer-rectifier is provided in the case of an A.C. supply, or a motor-generator in the case of a D.C. supply, and these represent an appreciable capital investment.

The thought occurs, therefore, why should we not endeavour to utilise the lighting supply direct to operate our valves, and, to proceed further, why not let it also replace our H.T. batteries and our grid batteries? One might argue that if it were too expensive to use the lighting supply to charge accumulators, would it not also be too expensive to use it direct? The answer is in the negative. In fact, as this article will show, it is possible to operate a multi-valve circuit without any batteries whatever, and not add more than a fraction of a penny to the weekly electric light bill.

Filament Lighting.

To explain the principle, we will consider first an ordinary crystal set with single valve amplifier. For simplicity, assume that the ordinary dry cell H.T. battery will be retained, and the electric light used only for the filament lighting. If the crystal set has a separate primary and secondary tuning circuit, no complications arise, and all that is necessary is to connect an adaptor on a twin flexible lead in place of the accumulator and insert it between the contacts of the electric light switch after the cover has been removed. A suitable adaptor can readily be constructed on the lines indicated in the sketch (Fig. 1). Care should be taken to see that the switch in question controls only one, or at the most two, lamps, otherwise the valve might be burnt out by an excessive current, and, as a precautionary measure,

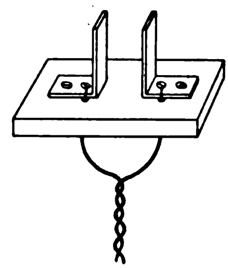


Fig. 1.—A suggested design of a clip for connection to an ordinary tumbler switch.

it is advisable to connect a filament resistance in parallel with the valve before attempting the experiment. In the case of an A.C. supply, a parallel resistance with a mid-point connection will be essential to prevent unpleasant humming noises; even with D.C. it is useful, as it is then possible to select the most effective point for the connection of the transformer return lead for the grid circuit. This point is made clear in the diagram (Fig. 3).

Electric lighting systems in various districts differ so much that it is difficult to outline the most suitable procedure in every case, but before making any experiments with valves on lighting circuits, it is an excellent plan to conduct a few tests to

determine which side of the circuit, if either, is earthed, and also to test individual switches to determine whether they are on the "live" or "earth" side of the lamps. The sketch (Fig. 2) shows how a lamp, which should be of the correct voltage for the supply, may be used to test the switch contacts. A full light

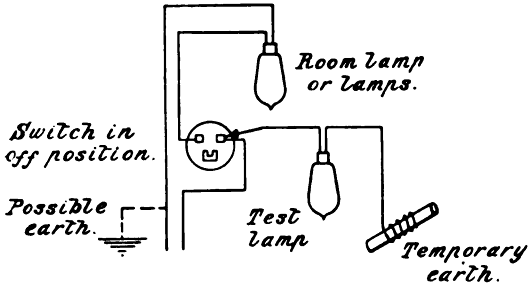


Fig. 2.—The earthed main should be found as indicated.

will indicate a live contact; a dull light, a live contact through a lamp or lamps in the house—these will also glow dimly—and no light at all will indicate a more or less effective earth. Switches should *not* be on the earth side of a lighting circuit, but they frequently are, and for wireless purposes such switches offer distinct advantages, and every endeavour should be made to operate valve filaments from the "earthed" side of a circuit.

The amount of current required for a valve will depend upon its type, but unless it be of the dull emitter type, it will probably require 0.6 to 0.7 amperes, which is approximately the current passed by two 60-watt lamps on a 200-volt supply.

Particulars of the supply voltage and the size of the lamps (in watts) will, from a knowledge that *current* (amps.) = *total watts* ÷ *supply voltage*, enable one to estimate the current which will pass through the valve filament when in series with the lamps at the switch contacts as previously explained. There is, of course, a slight voltage drop across the lamp terminals, but with the present day metal filament lamps, the insertion of the valve or valves makes no appreciable difference in the amount of light, hence the lamps can still be used for illuminating purposes.

The diagram (Fig. 3) shows a simple form of circuit which gives excellent results, and as the H.T. battery will last many months, it can be enclosed in the set, and the whole built up into a compact, self-contained unit which will practically banish all battery cares.

An extension of the idea is to add a second amplifier (Fig. 4), which, it will be observed, can readily be done by arranging the two valves in series, and incidentally, on a D.C. supply, this circuit arrangement permits the use of a negative bias on the grid of the second valve by taking advantage of the voltage drop across the first, but obviously the current must flow in the right direction, as indicated in the diagram. There is also no difficulty in providing a bias for the first valve, as all that is necessary is the addition of a non-inductive resistance (R1) of from 4 to 6 ohms in series with the negative lead feeding the first valve. Various refinements can be added, such as an adjustable resistance of a comparatively high value, bridging each filament so that each valve may be regulated

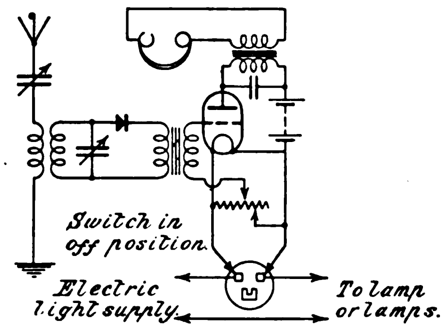


Fig. 3.—Here the filament is heated by D.C., and a resistance is connected in parallel, from which the correct grid bias is obtained.

independently, and, if desired, a noise eliminator consisting of inductances and condensers, could be added to the filament circuit should the greater magnification due to two valves bring commutator ripples, etc., into too great a prominence. The writer finds, however, that by exercising care in the selection of the particular points on the filament circuit at which tappings are taken for the secondary tunings and transformer returns, these extraneous noises can be reduced to a negligible quantity without complicated noise eliminators, although, when using the electric light supply in place of the

H.T. battery, a simple form of filter circuit or " noise killer " may be added to the plate circuit with distinct advantage.

Eliminating the H.T. Battery.

The preceding remarks are based on the use of a dry battery for supplying the anode potential, but there is no reason why the lighting supply should not be utilised for this purpose as well as for filament lighting. In the case of an A.C. supply, certain complications exist, and although for high power valves A.C. is very convenient, its use necessitates the introduction of additional rectifying valves and other apparatus, and, therefore, it is proposed now to confine our attention to D.C. working.

Before the electric light supply can be used for the anode or plate circuit, it is essential to know which wire is positive. This can be detected by noting which of two strips of lead turn brown when inserted in acidulated water. If the wire on the brown strip (*i.e.*, the positive) happens to be on the live side of the circuit, all is straightforward, but should the positive be the " earthed " side, the valve filaments and associated apparatus must be at the plate voltage above " earth." Indirectly this is an advantage, as the capacity effects of one's hand on the adjustment of tuned anode circuits is thereby reduced, and further, the possibility of shocks from the receiving portion of the set is minimised. Care must be taken to avoid contacts between the aerial tuning circuit and the remaining portion of the set, although if the aerial condenser is inserted on the earthed side of the inductance, such contacts are of minor importance.

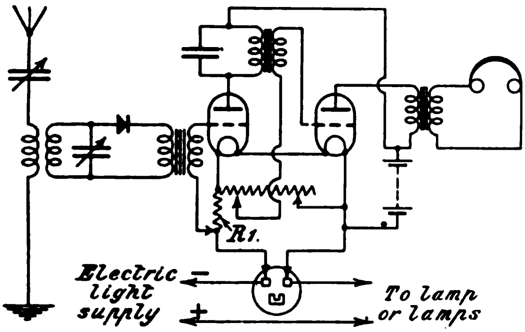


Fig. 4.—The grid bias for the first valve is obtained from a resistance R1 in series with the filament circuit.

To obtain the desired voltage for the anode circuits, a potentiometer should be arranged by connecting two or three lamps in series. The current for these lamps will be of small magnitude, but it can be taken in such a way as to augment the current flowing in the filament circuit (see Fig. 5). By altering the number of lamps in series or by using lamps of larger or smaller capacity, the amount of current taken by the potentiometer can be adjusted to any desired degree. This is an important feature, and can often be used to advantage to secure the fine adjustment so desirable in the filament circuit if the very best results are required.

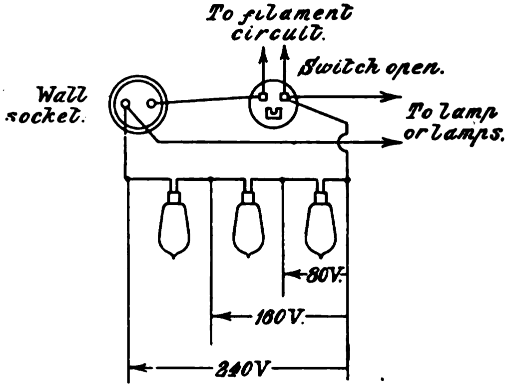


Fig. 5.—The anode voltage is taken from lamps arranged as a potentiometer.

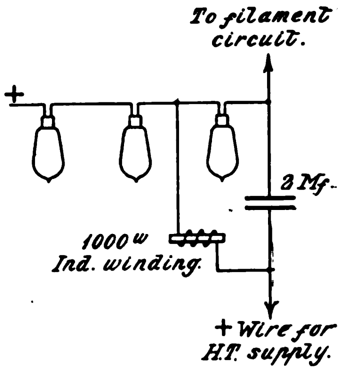


Fig. 6.—A filter circuit to reduce commutator ripple.

The number of lamps necessary in the series circuit of the potentiometer will depend upon the plate voltage required, and upon the voltage of the supply. As an example, three lamps of equal capacity used

on a 240-volt supply will enable one to tap off approximately 80, 160 or 240 volts as required. The latter value is hardly likely to be required, and, moreover, it would not be advisable to tap it in this manner. Modifications of this plan will suggest themselves whereby lamps of unequal capacity may be used in series to obtain intermediate voltages, remembering always that the larger the lamp (in watts) the lower the voltage across its terminals.

Having arranged the potentiometer circuit and selected the point at which the H.T. connection will be made, a simple form of "noise killer" should be constructed. This may consist of a highly inductive winding of about 1,000 ohms resistance with an iron core, such as an old telephone transformer or an old inter-valve transformer—so long as one winding is still undamaged—connected to a Mansbridge 2 mf. condenser, and arranged in the H.T. supply wire (see Fig. 6). This noise killer is not essential, and where loud speakers are used, possibly the slight hum usually present when the noise killer is absent will not prove objectionable, but it is a minor complication, and is certainly well worth fitting.

If desired, several tappings can be taken off the potentiometer, and the most suitable value selected for the H.T. voltage for each valve in the circuit, but unless valves of various types are used, this is hardly necessary, since by correctly adjusting the negative bias on the grid, as previously mentioned, it is possible to work each valve at its maximum efficiency. Those unacquainted with this method of control will be pleasantly surprised at the purity of tone obtainable, and, incidentally, the scheme of operating valves from lighting mains as put forward in this article gives extraordinary facilities for accurate grid adjustment.

A diagram (see Fig. 6) shows a three-valve circuit which gives very good results on a loud speaker. In this case the supply is 230 volts D.C., with the positive earthed. The circuit consists of the usual one-valve H.F. with tuned anode, crystal rectification, and two valves L.F., the unusual feature being, of course, the method of supplying the necessary current. The two lamps on the filament circuit are used for ordinary illumination, and the only additional current taken from the mains is the potentiometer current, which is considarably less than one-tenth of an ampere.

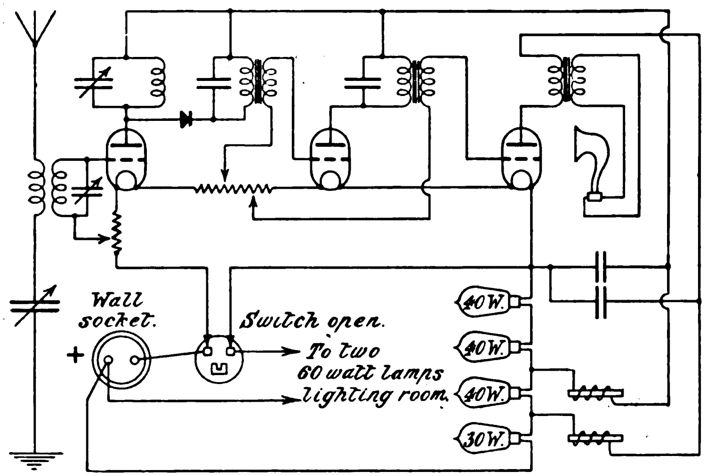


Fig. 7.—A complete loud speaker circuit operated entirely from direct current mains. The method of obtaining the correct grid biases should be noted. The H.T. is obtained from lamps arranged as a potentiometer, and passed through a smoothing circuit.

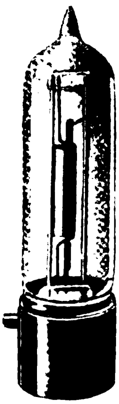
We should be obliged if holders of transmission licences, whose names do not appear in our "Radio Call Bock," would kindly forward particulars of their call and location.

Dull Emitter Valves.

Owing to the great interest which has recently been aroused in dull emitter valves it seemed that some collective data would be of value to our readers. Accordingly we have tested some eight representative types and the summarised results will be found below, together with certain details of manufacture.

During the last eighteen months the number of dull emitter valves has gradually increased until at the present time it is possible to purchase some ten or eleven different types. The development of the dull emitter has been a more closely-guarded secret than any other manufacturing process connected with radio engineering, and consequently it is extremely difficult to set down any really extensive and useful data. Moreover, in dealing with dull emitters in general, it must be remembered that there are at least three different types of filaments, and here, again, it is very difficult to make comparative remarks.

In the ordinary triode the electronic emission is obtained by heating to incandescence a fine wire made of tungsten or similar metal. It has been found that, in order to secure a sufficiently dense emission, it is necessary to make the wire filament very bright, and this, of course, requires a considerable number of watts. The object of the dull emitter is to obtain the same filament emission with only a fraction of the energy previously required to render the ordinary filament sufficiently incandescent.



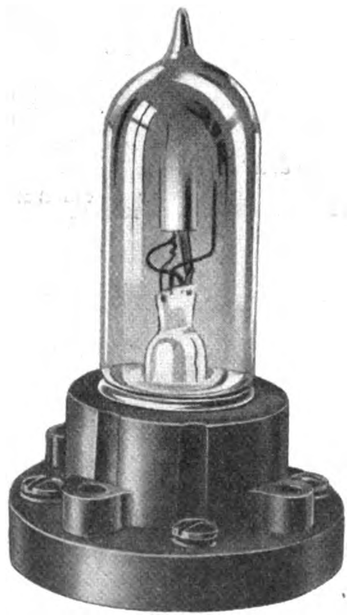


Fig. 1.—The Weco peanut, on the left, and the UV199, on the right, are the smallest dull emitters. It is understood that the latter type will shortly be placed on the English market under another name.

The ordinary thermionic valve was, therefore, taken as a basis of working, and experiments were conducted on various filaments. It was well known that certain oxides of the "earthy" elements would emit copious streams of electrons when heated only to a very low temperature, and consequently an attempt was made to utilise these. The obvious procedure was to incorporate some thorium compound, for example, into the ordinary filament, and then gently heat it

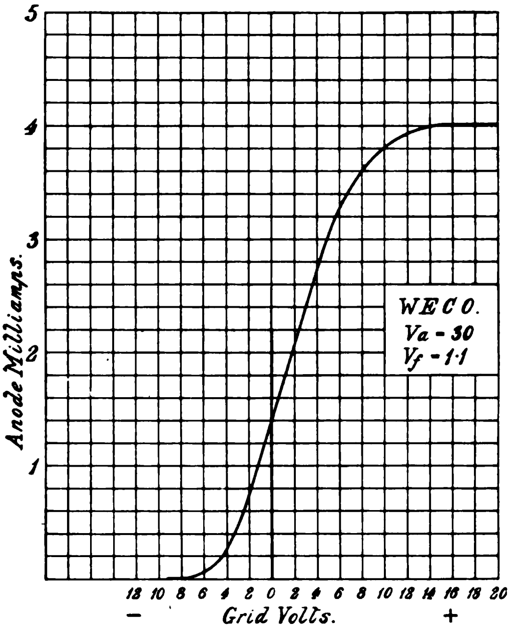


Fig. 2.—Although a spot reading gives a saturation current at 4 milliamps., it is not advisable to work above ·8.

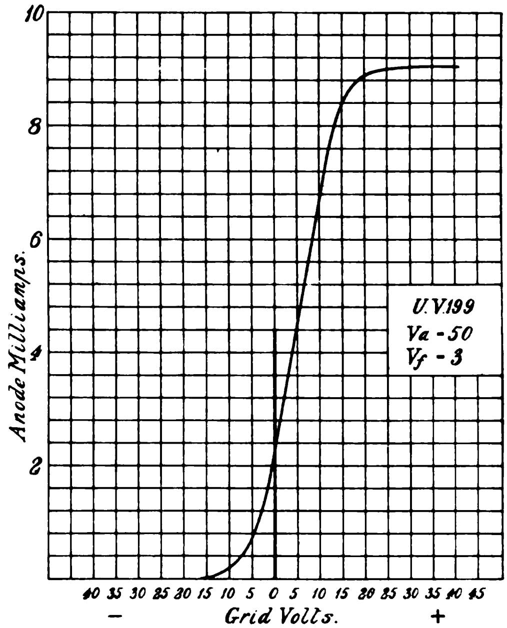


Fig. 3.—At zero grid volts a large current is obtained with an anode potential of 50 volts.

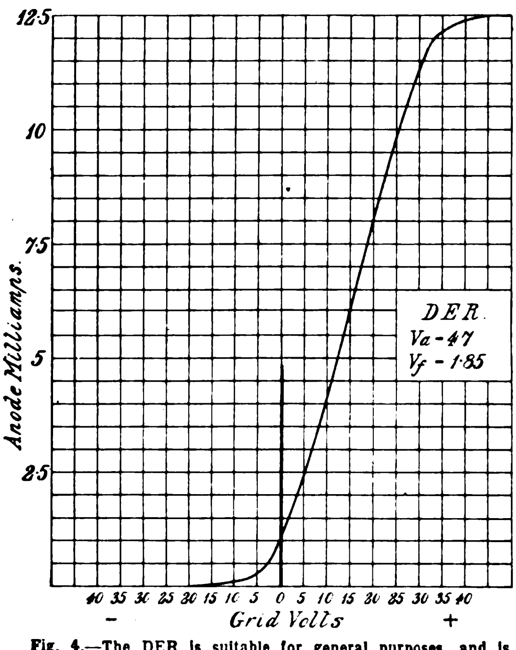


Fig. 4.—The DER is suitable for general purposes, and is comparable in performance with the R type.

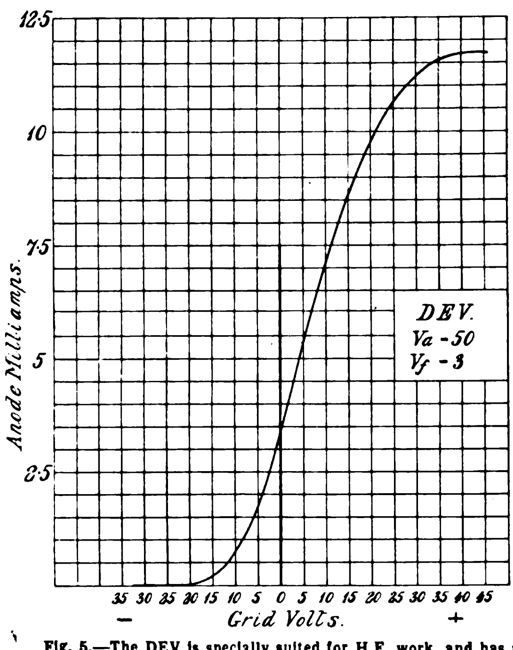


Fig. 5.—The DEV is specially suited for H.F. work, and has a very high input impedance.

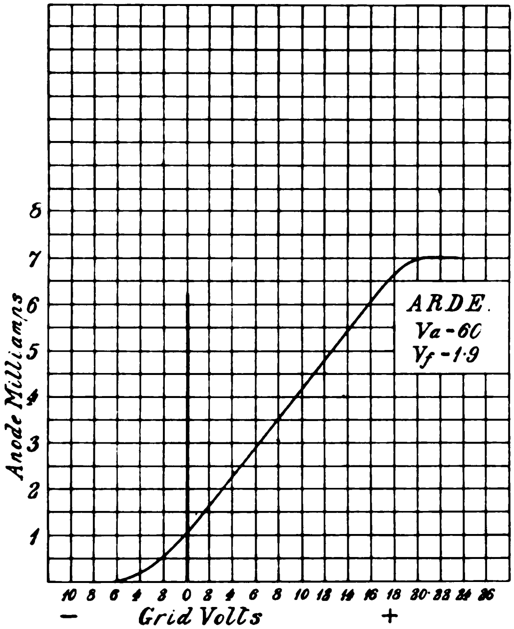


Fig. 6.—The ARDE is a useful general purpose valve, and shows good characteristics.

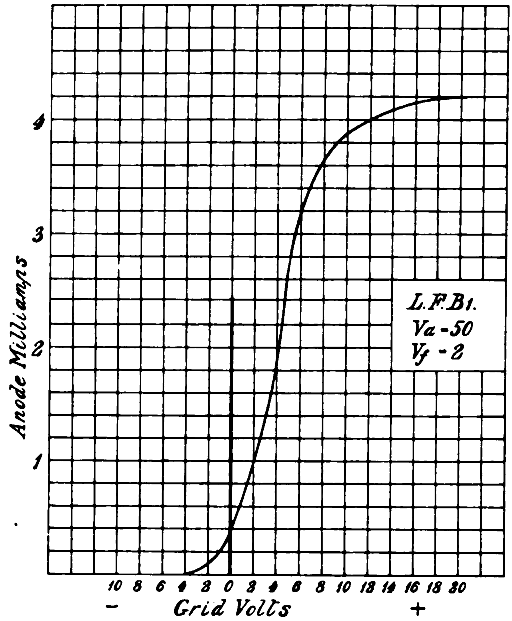


Fig. 7.—The L.F.B1 is a general purpose valve somewhat similar to the O.R.A.

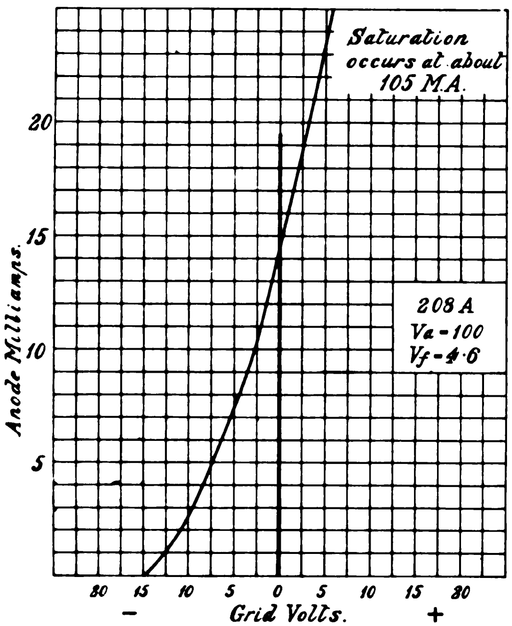


Fig. 8.—The 208A has a very large emissivity and is an excellent amplifier.

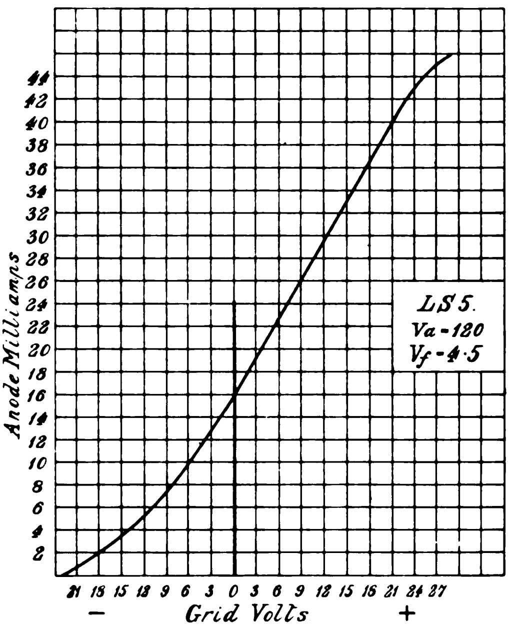


Fig. 9.—The low impedance of the LS5 at a low anode voltage makes it extremely useful.

until sufficient emission was obtained. This, of course, is a very fundamental and almost crude explanation of the principle involved, and considerable experimental work was necessary before the idea became practicable. Of this class of filament there are really two types, the coated platinum strip and the thoriated tungsten wire.

A filament of the latter type is used, for example, in the DER, and contains about 5 per cent. of thorium and thorium compounds. When it is heated to a low temperature a type of diffusion occurs, and it is believed that there is always a layer of pure thorium on the surface of the filament which has a very great emissivity. As the layer is very unstable every precaution has to be taken to remove any residual gases, and consequently a very high vacuum is employed. This feature is very beneficial, as it results in a much higher grid filament. As a further precaution, the inside of the tube of some thoriated filament valves is coated with a "getter" or a substance which combines more readily than the filament with contaminating gases.

There is always a danger of over-running a thoriated filament, which breaks up the thorium layer. Originally this defect was cured by heating the filament for about half an hour with the anode voltage cut off. A more recent method is to apply a high voltage for a short period to the filament, but it is certainly not a procedure to be recommended to the amateur. Should the anode become heated and residual gases released they are likely to attack the filament, which can be rectified by the above method. Partly on account of this, too high an anode voltage must be avoided unless, of course, a negative bias is applied to the grid. It is believed that the life of a valve of this description is of the order of 1,500 hours if carefully handled.

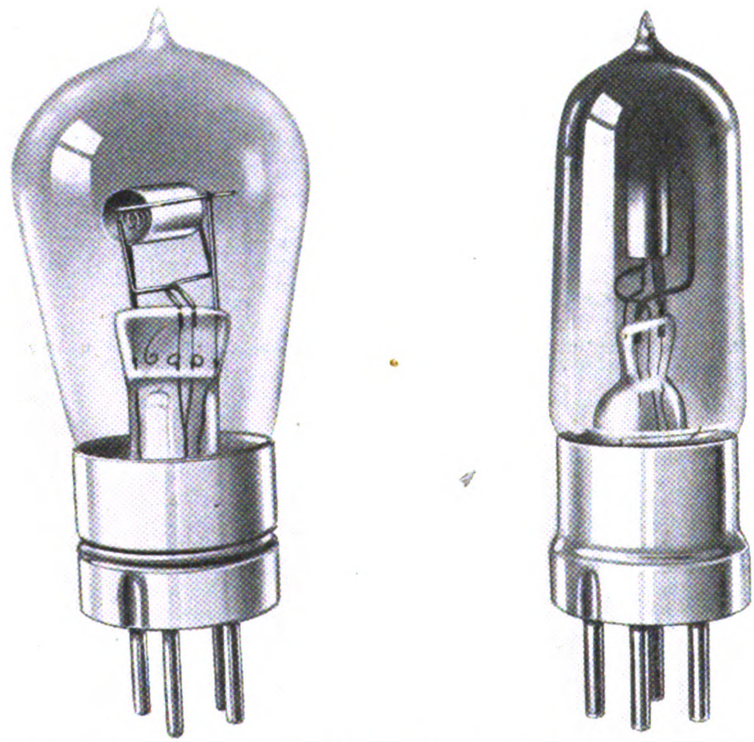


Fig. 10.—The DER is now being made with horizontally disposed electrodes, while the ARDE is a tubular valve with a vertical filament.

Mention has been made of another form of filament consisting of coated platinum, and

this type is employed, for example, in the "Weco" peanut tube and the "208A" amplifier, of which mention is subsequently made. This type of filament probably has its origin in the Wehnelt lime-coated filament, which dates back to 1903. When the thermionic valve was applied to line tele-

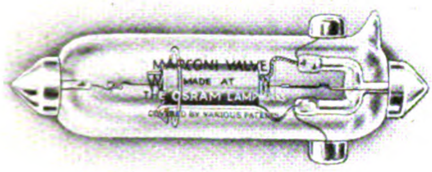


Fig. 11.—The DEV, in appearance, is almost identical with the V24.

phony, a valve requiring a low wattage, and capable of giving a large emission, was found necessary, and consequently experiments on the coated filament were recommenced. In

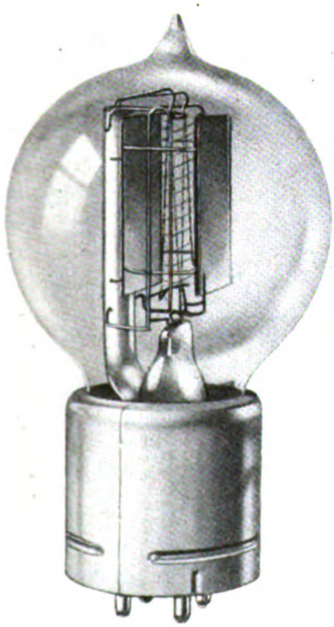


Fig. 12.—The 208A Amplifier is of very rigid construction, and has a substantial strip filament.

its present condition the filament is prepared from a platinum alloy drawn into a fine wire, which, in large valves, is rolled flat to give a greater surface. In the original Wehnelt filament the coating was not very tenacious, but the difficulty has been overcome by the following method of manufacture :—Barium and strontium oxides are each mixed with a "carrier" consisting of wax or resin, and are applied alternately to the filament in thin layers, and are then baked on to it. In addition, between the successive applications of oxides, the filament is flashed at a high temperature for a short interval, and finally, after about sixteen layers have been applied the filament is baked at a high temperature. The coating is so secure that it has to be scraped from the wire with a sharp knife before electrical connection can be made to the ends.

Fig. 13.—In the LS5 a flattened cylindrical anode and a carbonised filament are employed.

Originally, the core of the filament was a platinum-iridium alloy, but the platinum alloy employed at the present time has a greatly increased thermal efficiency. It was also found that by employing only barium oxide for the coating a greater thermionic activity was obtained, but the life of the filament was reduced.

Dull Emitter Valve Data.

Type of Valve.	U.V. 199.	W.E.C.O. (Peanut).	D.E.R.	D.E.V.	L.F.B.I.	A.R.D.E.	208A.	L.S.5.
1. Anode Potential in Volts ..	50	30	47	50	50	60	100	120
2. Filament Voltage	3	1·1	1·85	3	2	1·8	4·6.	4·5
3. Filament Current in Amps...	0·06	0·25	0·4	0·245	·25	·3	1·28	·8
4. Saturation Current in Milliamps.	9·2	4	12·5	11·75	4·3	7	105	50
5. Current at Zero Potential ..	2·52	1·4	1·2	6·5	·4	1·1	15	16
6. Grid Potential at Zero Current	—17·2	—8	—18·2	—22·8	—4	—6·4	—15	—24
7. Slope of Curve	5 : 2	1 : 0·6	5 : 1·2	5 : 1·5	2 : 0·5	4 : 1·25	2·5 : 3	3 : 3·2
8. Purpose of Valve	G.	G.	G.	H.F.	G.	G.	P.A.	P.A.
9. Filament	Thoriated	Coated	Thoriated	Carbonised	Thoriated	Thoriated	Coated	Carbonised
10. Manufacturer	G.E.C. of America	Western Electric	M.O. Valve Co.	M.O. Valve Co.	Mullard Valve Co.	Ediswan	Western Electric	M.O. Valve Co.

The above data has been derived from the curves accompanying these notes, and should be self-explanatory. Column 7 defining the slope, such as "5 : 2," indicates that, on the straight part of the curve, a charge of 5 grid volts produces a charge of 2 milliamps. in the anode circuit. The letters in Column 8, indicating purpose of the valve, are as follows :—G, General Purpose ; H.F., H.F. Amplifier ; P.A., Power Amplifier.

It must be remembered that the above data is merely representative, it having been obtained under suggested working conditions, but the various voltages are all capable of slight variation.

A valve containing a coated filament requires exhausting to a very high degree of vacuum, partly because a hard vacuum is required, and partly because it is impossible to obtain the same "clean up" effect as with a tungsten filament. Full emissivity is obtained at a temperature of about 1,000° C., but it is interesting to note that the valve will sometimes function at a black heat; that is, when the heated filament is invisible in a dark room.

Mention has also been made of the carbonised filament, which is used, for example, in the L.S.5 valve. Unfortunately, it is not possible to give any details of manufacture at the present time.

Having now considered the various filaments which are employed, brief mention will be made of the several types of dull emitter valves which are available to the experimenter. Owing to the dissimilarity of the various valves, and the purposes for which they are intended, it is not possible to make any comparisons, and accordingly a table of data has been prepared and grid volt anode current curves have been plotted under working conditions recommended by the makers. It will be noticed that all the curves have been taken to saturation by means of spot readings, but the small dull emitter should not be used at such high current densities. The zero grid volt ordinate is shown on each curve, and this should certainly be taken as the cut-off limit.

The Amateur Transmission Movement.

So much interest has been aroused in experimental circles by Radio Transmitting Societies, that we think our readers will welcome the following details of the various organisations and the objects it is hoped to achieve. We also present a summary of an excellent lecture delivered by Captain Round at the same meeting.

Transmitter and Relay Section of the Radio Society of Great Britain.

A NEW section of the Radio Society of Great Britain has been formed, to be known as the Transmitter and Relay Section. This new section has been planned because the British Wireless Relay League has been merged in the Radio Society of Great Britain. The objects of the Section are (1) to promote inter-communication between experimenters, and thus assist them to improve their apparatus; (2) to join hands with similar organisations overseas; (3) to investigate the quality of the transmissions in various directions at different hours; (4) to establish a collection of wavemeters and other useful apparatus for loan within the Section. In supporting the Section, the Radio Society will protect the principle of "Freedom for Experiment." All persons holding experimental licences are eligible for election to the new section in one or other of two classes, according to whether they are members of the Radio Society or an affiliated society, or not. We hope to publish further details when available.

Radio Transmitters' Society.

At a meeting of the above newly-formed Society, held on Wednesday, October 10, the chair was taken by Captain Ian Fraser.

In opening the proceedings, the Chairman said :—

Gentlemen, you will recall that at the inaugural meeting there was a very sharp division of opinion amongst members as to what should be the attitude of our Society with regard to the Radio Society of Great Britain. Some held that we should form no new society at all, but, rather, should allow the Radio Society to develop a Transmitters' Section. Others held that we should have nothing to do with the Radio Society. Finally, it was agreed that the matter should be left to be handled by your Committee, and that we should start by forming an independent society with a committee con-

sisting of transmitters. Well, we have formed this Society, and, in spite of the division of feeling amongst our members, or our potential members, at one of our Committee meetings I suggested a conference with the Committee of the Radio Society. I arranged one, and went with our Secretary, Mr. Marcuse, and our Treasurer, Mr. Walker, to meet three of their members. We asked if some means could not be found whereby competition in the matter of seeking for membership might be avoided. One of the members of their party who met us was good enough to say that he appreciated our reasonable attitude, and we were convinced that no possible blame could be laid on our side if peace and harmony, and some joint arrangement, were not come to. However, I had a letter to-day from the Secretary of the Radio Society, in which it was stated that, in view of the similarity between our objects and the objects of their newly-formed Transmitters' Section, their Committee did not see their way to discuss further the question of affiliation or any other means of co-operation.

Now I should have thought, personally, that the fact that our aims and objects were similar was a reason for co-operation and not a reason against it. Be that as it may, we know that we, as a Society, are not wanted by the Radio Society. That may be good or bad—I reserve my opinion upon that—but we are at the parting of the ways. We are either to go on and endeavour to rally transmitting opinion around us, endeavour to lead transmitters to see that a Society exclusively concerned with their interests and not serving other communities as well, that a Society with a Committee of persons who have some knowledge of transmission, that a Society having a membership extending throughout the country, is a good thing for them; or else we have to pack up. Even if we pack up to-morrow we have stirred matters up amongst transmitters, and we have led to great activity in another quarter, which will, I hope, produce good results.

However, it rests in your hands whether we die or not. Personally, I think we can render useful service, and when one considers that the Broadcasting Company, to serve its public properly, must extend its hours of working, when one knows that an extended range of wave-lengths is under consideration for application to their work, when one realises that we are extraordinarily scattered, and that we transmitters, as a whole, throughout the United Kingdom have not any Society apart from this one which is solely concerned with our interests, when transmitters, as a whole, have it pointed out to them that whatever committee at present exists representing, or aiming to represent, them has to serve other masters, whose interests are not always theirs, I think we ought to be able to make out a case to amateurs all over the country for joining us.

If it is felt that we should go on it will be the intention of the Committee immediately to send a letter to all amateurs whose names we have throughout the country to ask them to become members of our Society at an annual subscription of 5s. We intend to develop relaying work and long-distance transmissions. We hope, perhaps, to be able to serve the Broadcasting Company, should they require observations from different points widely scattered, by people who are competent to make those observations. We hope generally to render a service to the community, for if we do not, then we are bound to be closed down. I think it must be our aim to organise in such a way that we can demonstrate to the powers that be that we do render some service in regard to research, in regard to the fact that we were available, those of us who were in the movement before the war, and would be available again in any emergency if we were needed. We must point this out to them, and we must try and rally them round us and seek to get a sufficient membership of transmitters to carry on a flourishing Society. If your Committee feels that you are with them in that project we shall go ahead.

In the letter which we propose to send round it is our intention to enclose a form which we are going to ask amateurs to fill up, saying that they support the following resolution and letter. If you approve of these I think your Committee can take it that you approve of our actions up to the present, and our general plans for the future. (Hear, hear.)

A vote was then taken upon the resolution and the following letter, and they were unanimously passed.

RESOLVED that the following letter, which has been read to, and approved by, seventy-nine amateurs holding licences for the transmission of wireless telephony and/or telegraphy, present at a meeting of the Radio Transmitters' Society, held at 6.30 p.m. on the evening of Wednesday, October 10, 1923, at the London School of Economics, be despatched to H.M. Postmaster General, and that he be asked, in the name of the above-mentioned persons, to give it his consideration, and grant the request made therein.

To H.M. POSTMASTER-GENERAL :—

SIR,—On behalf of the Radio Transmitters' Society we have the honour to send you the resolution enclosed, and this letter, which is referred to therein.

You will be aware that the Radio Society of Great Britain have for some time past represented to you the views of the amateur movement, and that in the absence of any other organisation the views, opinions and claims of amateurs throughout the country have in the main been brought to your notice through this body.

We have now to inform you that the desire of a number of amateur transmitters to have a Society representing their special interests, and controlled by a committee of persons, themselves amateurs with practical experience in transmission work, has resulted, after two meetings, at each of which approximately 100 such persons were present, in the formation of "The Radio Transmitters' Society." A copy of the constitution approved by these persons at an inaugural meeting is enclosed for your information.

The members of our Society, and many other persons who have the requisite qualifications for membership, and who have intimated their approval of the Society, but who have not yet, owing to the fact that our organisation has only been in being for two or three weeks, become members, desire us to call your attention to the foregoing facts, and to ask you to give representatives of our committee an opportunity of interviewing your officers with a view to discussing with them the position of the amateur transmitter in general, and what steps, if any, can be taken to ensure the maximum of freedom for experimental work and the minimum of interference with broadcasting and other National services.

In particular we are desired to point out that we note with pleasure your decision to appoint a representative Board whose function it shall be to advise you upon all matters affecting Broadcasting in the United Kingdom, and that amongst the interests to be represented special mention is made of Radio Societies.

We venture to express the opinion that it is in the public interest that the amateur experimenter, properly controlled and licenced to utilise relatively low power for transmission work, should be encouraged in his research and experimental work, and that the best method of securing this without causing interference with or inconvenience to other interests is that our particular section of the amateur world should be represented upon your Advisory Board.

While we recognise that the number of persons holding transmitting licenses is a small one compared with those having various types of receiving licenses, we venture to submit that our qualifications for serious experimental work are, in virtue of the severe tests you have rightly put upon us before granting our licences, of such a nature as to make our contribution to the progress of wireless technique worthy of special consideration.

Further, we hold by your permission the power of interfering with other transmissions to a more or less extent, and we submit that it is in the public interest that we should be placed in a position in which proper representation of our interests can lead to co-operation and mutual understanding.

We enclose a list of our committee and officers, and would venture to call your attention to the fact that the majority are experimenters of long standing.

We might add that a copy of this letter and resolution is being sent to all transmitting amateurs in the United Kingdom who were not present at the meeting referred to, and that we have every expectation that the response we shall receive will be of such a nature as to indicate that in the important matters referred to in this letter we have a substantial backing.—Yours faithfully,

(Signed) P. P. ECKERSLEY.
IAN FRASER.

Captain Round's Lecture.

The Chairman then introduced Captain Round, chief of the Research Department of the Marconi Wireless Telegraph Co., Ltd., and said that it was a great honour for an audience of amateur transmitters to have a lecture by one who was probably the most eminent radio-engineer in Europe.

The lecturer opened with a description of some observations during experiments on a duplex wireless telephone system between England and Holland. It was noted that, under certain conditions, the speech received was considerably distorted ; and in further experiments in reception over land from one of the stations the speech was so distorted as to be unintelligible. As the wave-length was 100 metres, and the effect had not been noticed on longer waves, it was thought that the shorter wave-length had some influence. The effect was more noticeable with a frame aerial receiver than with a vertical aerial. The phenomenon was chiefly observable at night, and this has been called a night effect.

The lecturer then turned to the consideration of night effect and broadcasting. He had observed slight night effect from 2LO at Cheltenham in January of last year, using a frame aerial. Not many other complaints of night effect, as distinct from fading, had been reported by listeners. The

equipment at 2LO last winter consisted of a master oscillator driving a main valve, so that carrier wave-length change was an impossibility.

In the summer of this year, for certain reasons, a simple self-oscillating system was resorted to, which, of course, would allow wave-length change due to any minute changes in the constants of the high-frequency circuits.

Lately a great many complaints had been received from listeners that the quality of 2LO *at a distance*, particularly the Norfolk area, was very poor, and not to be compared with either the quality near to, or the quality of other broadcast stations possessing a master oscillator. The lecturer himself, by imitating the conditions of reception at a distance, had observed the poor quality, and had, furthermore, shown that the point of tune chosen on the receiver influenced the quality—an effect observable with grid control, which is a type of control relying upon wave-length change.

Captain Round went on to point out that there was evidence that the deep modulation at present in use at 2LO might, with the high-frequency circuits in use, exaggerate the wave-length change.

Combining the well-known theories and experiments of T. L. Eckersley on the night effects produced by the Heaviside layer, the duplex experiments, and the recent circuit experiments at 2LO, the lecturer promulgated a newer theory to show that this speech distortion at night was due to carrier wave-length modulation being connected with amplitude modulation by the interference bands existing over the earth's surface at night.

The solution of the problem will lie in designing a method of control that will not tend to change the wave-length—the master oscillator is no real cure because bad quality will be produced near by, certainly by a system which is trying to change wave-length but cannot.

Very slight changes day by day are being made in the circuit at 2LO to eliminate, as far as possible, this wave-length change. Certain distant observers' reports are being used to determine the effect of the changes.

The lecturer turned next to the question of quality, the design of microphones, and the theory of corrections. He explained that probably the best arbitrary arrangement was to get the maximum of overall control at the transmitter by trying to give every sound frequency equal amplitude of control. This gives on ordinary telephones and loud speakers a fair result. He had, however, taken curves representing the amplitude of a diaphragm over a large range of frequencies necessary to give equal audibility, and he found that the amplitude of the lower frequencies had to be hundreds of times greater than the higher ones. It would be impossible to give an electrical modulation proportional to this amplitude to the transmitter, as the overall control would be extremely weak, being limited by the maximum allowable for freedom from over-control; hence the arbitrary basis of equal amplitude for equal audibility for all frequencies. Correction must then take place in the receiver. He had taken curves of various loud speakers and 'phones, and these showed a marked resonance in the middle register, which resulted in a further diminution of the bass sounds. It was possible, however, with a given pair of 'phones, to apply an overall correction. The results were extraordinary, and an approach to true duplication of the original quality had been made. Some loud speakers now on the market had been adjusted by the makers so as to approximate to good quality over some part of the frequency scale, and, in consequence, they were curiously more difficult to correct to really perfect quality than a bad resonant loud speaker having one single pronounced fault.

Captain Round's lecture was received with great enthusiasm by the transmitters present, and a discussion on various points was carried on after, when many questions were asked by amateurs and answered by Captain Round.

The Chairman then announced that Capt. P. P. Eckersley had been asked by the Committee of the Radio Transmitters' Society to become president of the Society, and had accepted this office. The amateurs present expressed their delight at this, and requested the Chairman to invite Capt. Round to become honorary vice-president of the Society. Capt. Round accepted this position, and a vote of thanks to him for

his interesting lecture was proposed and carried.

Any person shall be qualified to be a member of the Society who is the holder of an experimental licence from the licensing authority of the country in which the person or persons reside for the transmission of wireless telephony or telegraphy, or any person regularly operating a transmitting station on behalf of such a licencee, or any person who, in the opinion of the Committee, is qualified to hold such a licence.

Full particulars of subscription, etc., may be obtained from the Hon. Secretary, Mr. Gerald Marcuse, Coombe Dingle, Queen's Park, Caterham, Surrey.

THE EXECUTIVE OF THE RADIO TRANSMITTERS' SOCIETY.

The following officers and committee have been elected :—

President .. Capt. P. P. ECKERSLEY (late Emma Toc).
Vice-President .. Capt. H. J. ROUND.
Chairman .. Capt. IAN FRASER.
Hon. Secretary .. GERALD MARCUSE.
Hon. Treasurer .. HAROLD S. WALKER.

Committee :

K. E. ALFORD (2DX)
F. L. HOGG (2SH)
D. KILBURN (5VR)
G. MARCUSE (2NM)
H. S. WALKER (2OM)
J. E. NICKLESS (2KT)
J. A. PARTRIDGE (2KF)
E. J. SIMMONDS (2OD)

Correspondence.

Tuned Anode Receivers.

To the Editor of EXPERIMENTAL WIRELESS.

DEAR SIR,—I must congratulate you most heartily on your first issue, which seems to me to be the first effort to approach its subject in a true technical manner, at any rate among journals available to the general public. I have been for years waiting for such a paper.

Nevertheless, my joy at patience rewarded makes me all the more critical towards the contents; and, while the articles appearing are all of exceptionally high quality, I wish to join issue with the author of "Tuned Anode Receivers." This distinguished officer is evidently a firm believer in the tuned anode circuit as against the transformer, but his arguments do not seem to me to be convincing.

In the beginning, with the words "It is one of the most efficient . . . and probably the most practical method," he begs the whole question: we want evidence please.

Early on page **34** he states of the transformer, "an extra tuned circuit is necessitated for full efficiency." I claim that this statement is erroneous. I have always regarded it as generally accepted, and it can certainly be demonstrated by analysis, that when two circuits are closely coupled, the capacity loading of either may be regarded as transferred to the other; in other words, the two circuits can be completely and efficiently tuned by a condenser across one of them.

When we compare such a close-coupled tuned transformer with the "tuned anode," we find one tuning adjustment in either case. In one circuit we have an extra coil; in the other we have a grid condenser and leak. I think, personally, there is little to choose as regards complication.

Naturally, where the second of the two valves is being used for grid rectification—and a leak and condenser will be used in any case—the tuned anode is appropriate; but there is now an increasing body of opinion to the effect that this highly efficient detecting system is prone to distortion. Where rectification is effected otherwise, or is not wanted, my own experience has been that the transformer, with its direct grid connection, is easier to handle, as would be expected.

I have not space to go into details over the step-up question and prove the point, and can only state that it can be shown that step-up is possible. Even if it were not, the transformer is on the *same* footing as the tuned anode, not one bit worse. I will quote the author against himself (on p. 33), " . . . the principles involved are the same, both . . . operating on the principle of self-induction."

As regards selectivity, this is, of course, a matter of the efficient design of the circuits. I have as yet seen no evidence to upset the theoretical result that, with sufficient care in design, the two systems will be identical. Summed up, my opinion (for what it is worth) is that Capt. St. Clair Finlay, in his admiration for a circuit of admitted excellence, has been led astray into condemning a rival circuit which is equally good, either circuit surpassing the other according to conditions of design and use.

"VERITAS."

SIR,—The writer is glad to see "Veritas's" trenchant criticism of his article on "Tuned Anode Receivers," as he regards free constructive discussion amongst experimenters as of the utmost value, and some such criticism is by no means unexpected. Are we not in this case, however, perhaps a little at cross-purposes?

To reply to his points *seriatim :*

(1) This does not appear to be a very revolutionary statement. Since both the efficiency and practic-

ability of tuned anode coupling for short waves is now generally recognised, and is not in doubt, surely elaborate evidence on the point is uncalled for in an article not intended to be a technical treatise on the subject. As to "begging the whole question"—that is not what the Editor said when confronted with the MSS.!

(2) Here "efficiency" in the general sense is intended. In coupled circuits where the value of k is made such as to commutate capacity-loading as applied to either, the transfer of energy will be largely, and maybe predominantly, capacitive, in which case the inductive characteristics will be submerged. "Selectivity" in inductively coupled circuits may be said to vary inversely as the square of k and is obtained in practice by limitation of Xm in transformers, since

$$\frac{Xm}{\sqrt{X_1X_2}} = k,$$

and this condition demands close-tuning of both primary and secondary for efficiency, which introduces a complication absent in the simple tuned anode arrangement. If, on the other hand, these principles are not to be observed, then there will seldom be any object in the adoption of the more complicated arrangement—which can, in fact, be shown to be such, notwithstanding the elimination of one or two variable capacities therein, since the leak in the one case and potentiometer (or leak and condenser) in the other cancel out, leaving on the one hand a simple fixed condenser, and on the other an inductance, the design and construction of which demand considerable care, to serve the same purpose.

(3) The use of grid rectification in the second valve being precisely the condition obtaining in the receiver under discussion, and this having been amongst the considerations weighing in favour of tuned anode coupling in this case, the point of this comment is not clear.

With regard to distortion in leaky grid-condenser rectification, whilst this is admissible in certain degree, the particular receiver concerned being intended primarily for the reception not of broadcast but of comparatively attenuated amateur signals, one of the main considerations before the writer in designing it was necessarily high sensitivity to *weak* signals, which provides sufficient reason for the adoption of this system of rectification. In practice the receiver in question is particularly free from distortion even with strong loud-speaker signals when intelligently constructed and operated, which may in this case be pre-supposed.

(4) (*a*) Here the writer expressly says *material* step-up, and thinks it will be conceded, without recourse to technicalities, that any gain possible in this direction will not in practice be such as in itself to warrant preference for either form of coupling as against the other.

(*b*) This is a *mis*quotation, as reference to the paragraph in question will show the author to be comparing similar principles in dissimilar applications, *i.e.*, H.F. auto-transformers with L.F. auto-transformers, and not with transformers at all. Moreover, it is incorrect to say that transformers and chokes operate on the same principle of simple self-induction as "Veritas" appears to suggest.

(5) This is in effect precisely what the article points out, and the remarks in question are intended to show, and is advanced as a consideration in favour of the simpler tuned anode arrangement. Actual superiority of the latter in the matter of selectivity is nowhere suggested.

(6) No condemnation of any system is intended or made—merely a comparison between two systems applicable to a given purpose. This purpose is specified in the article and the respective systems discussed relatively to it, quite fairly it is believed, and here the writer would refer "Veritas" to the summing-up on p. 35, l. 33, which reads: "It will therefore be clear that transformer coupling has *for our purposes* no real *advantage* to offer over the tuned anode method . . . etc.," and scarcely constitutes a condemnation of transformer coupling as such.

It should be borne in mind that transformers, compared with tuned anode coils, require very careful design and construction to be fully successful, and the question is merely raised as to whether—on the Irish principle that "the better of two equally good things will be the simpler"—the former have really much to claim over the latter in the majority of applications.

This surely does not quite justify the horrid impeachment of being "led astray" and of being wedded to one system to the blind persecution of another; and it may surprise "Veritas" to learn that the author has himself—faithless traitor!—found a certain amount of use for transformers in the course of his seventeen years' addition to ether-shaking, and is actually still quite partial to them—in their right place.

He is sorry if "Veritas" finds him unconvincing—*of course* he does if he has the true experimental spirit—but, perhaps, this is only because we are, after all, still at a stage in Radio where an open mind is better than—a closed circuit, for example!

CAPT. ST. CLAIR-FINLAY.

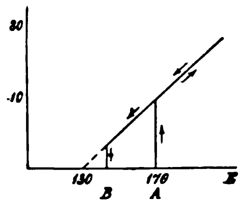
Neon Lamps.

To the Editor, EXPERIMENTAL WIRELESS.

SIR,—I have read with interest Mr. E. H. Robinson's article on neon lamps. As I have been experimenting with neon lamps for some time, perhaps I may be allowed to make the following suggestions:—

Firstly, I do not think that the characteristic curve which he shows gives the reader a clear conception of what occurs, as it leaves out a most important point. This is, that the lamp will not flash on until a voltage is reached which is considerably higher than the extinction voltage. Also it gives the reader the impression that the line is curved, when, however, if sufficient time is given for the temperature of the gas in the bulb, and consequently the gas pressure, to attain a steady value, it will almost universally take the form shown in Fig. 1. This shows that a high voltage A has to be applied to start the glow. After this, the voltage and current both follow a linear law for both increasing and decreasing values of voltage until the voltage B is reached. At this point the lamp will usually go out, but the current may often be brought down to zero if it is done sufficiently gradually.

Secondly, with regard to the production of oscillations. The condenser is shown connected across the lamp, but it may be connected with equal success across the resistance. Also the wave



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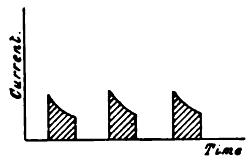


Fig. 2.

shape has evidently been deduced from the curved characteristic. If the straight line characteristic is taken a wave shape as shown in Fig. 2 will be obtained. This can be verified experimentally by means of an oscillograph.

Thirdly, with regard to the Anson relay, he states that the plate current rises on the arrival of a signal. Such, however, is not the case, as the current is at a maximum when there is no signal, and falls on the arrival of an impulse.—Yours truly,

H. ANSON.

SIR,—Dealing with Mr. Anson's first point, I should like to draw attention to the fact that in nearly all cases where a neon lamp is applied to radio purposes we are concerned, not with the static characteristic of the lamp, but with the dynamic characteristic, that is, the characteristic showing the relations between the potential across the lamp and the current through it when conditions are varying rapidly. Fig. 2 in my article is not a static characteristic curve, but it was taken from a fairly rapid series of spot readings, and it therefore represents the usual dynamic working conditions more closely than does Mr. Anson's linear characteristic. A curve obtained by waiting for long intervals between successive readings is useless for high-frequency or even low-frequency work. As to the difference between ignition and extinction voltages I have drawn attention to this in the text of my article. The curve in Fig. 2, as clearly stated, only represents the extinction path.

With regard to the wave-form of pulsations produced by a neon lamp, let me say at once that I have not had the opportunity of making oscillograms. Much, however, may be learnt by the use of a simple rotating mirror, and this has indicated that the wave-form is by no means the same for all frequencies, the dark intervals being relatively shorter in comparison with the ignition periods for higher frequencies. I do not doubt for a moment that Mr. Anson has obtained oscillograms of the form he indicates, but he gives us no clue as to the circuits he used in obtaining them nor of the frequency. The chief object of Fig. 5 in my article was to illustrate the fact that a neon lamp does not produce a sine wave. I should also like to point out that in nearly all practical applications of the pulsating neon lamp there is some inductive circuit in series with the lamp. Take, for instance, Fig. 6 in my article, each discharge of the condenser C1 has to pass through the inductance L1. If the pulsation frequency is at all higher or the inductance L1 of appreciable size it will be a physical impossibility for the discharges to take place exactly in the form indicated by Mr. Anson's oscillogram, but the vertical sides will have to slope somewhat and the top corners will become rounded off. Under these circumstances the pulses will tend to assume the form indicated by myself.

I am interested to hear about the alternative position for the condenser, namely, across the supply resistance. For producing oscillations of any amplitude, however, it would be a distinct disadvantage to have a resistance shunted across one's condenser as the resistance would produce unnecessary damping effects.

Although an Anson relay may be made to work with the relay valve functioning either at the upper or lower bend of its characteristic curve, I was unaware at the time of writing my article that the practical form of the instrument is made to work on the upper part. It will be remembered that a demonstration was recently made before the Radio Society of Great Britain, in which the lamp operated at the lower bend.

E. H. ROBINSON.

Efficient Transmission.

To the Editor of EXPERIMENTAL WIRELESS.

SIR,—As a result of my article on "Efficient Transmission" I have received considerable correspondence, and it appears that I did not make one point clear. The whole of my remarks were confined to one particular wave and aerial arrangement. The aerial is supposed constant throughout, except for the addition of a counterpoise. Adding a counterpoise will bring down the fundamental slightly, and also the effective height will be reduced slightly, but these are more than counterbalanced by the enormous decrease in the "loss" resistances. Otherwise it might be thought I advocated an aerial 10 ft. high so as to get a huge aerial current!—Yours faithfully,

FREDERIC L. HOGG (2SH).

UNNECESSARY RADIATION.—At a recent meeting of the Radio Transmitters' Society the subject of jamming on amateur wave-lengths was discussed. Much can surely be done by the elimination of harmonics and the use of selective receiving apparatus, but the old adage, "Prevention is better than cure," seems to be a better solution of the problem. Authority to transmit is only granted on the condition that the tests should be made for experimental purposes, and it is extremely doubtful if some of the transmissions now taking place represent experiments of any real value. We refer particularly to "test records" and such remarks as "My radiation is ·5; how are you getting me?" It is very hard to believe (as a result of following consecutive communications between two stations) that many of the experiments could not have been better carried out on an artificial aerial. It would be a step in the right direction if transmitters would give a little more thought to the use of non-radiating aerials.

Experimental Notes and News.

Wireless experimenters will have heard with very great regret of the death of Mr. J. H. Gregory, of Highgate, through a fall from a tree while engaged in fixing an aerial. Mr. Gregory was very well known in North London wireless circles, and was a student in medicine at Cambridge. Many experimenters have taken great personal risks when fixing aerials, but we believe that this is the first fatal mishap to be recorded.

* * *

The experimental side of wireless work is strongly represented in an excellent syllabus of forthcoming lectures which has just been issued by the Leeds Radio Society. The Society has over one hundred and fifty members, and holds comprehensive permits from the Postmaster-General for experimental work both in transmission and reception. We are interested to note that EXPERIMENTAL WIRELESS is already officially scheduled as being available for reference at the Society meetings.

* * *

The Manchester Wireless Society is another live society with a strong list of popular and advanced lectures. We notice in their list a paper to be read on February 27 by Mr. J. McKernan on "Selenium Cells," which is to be illustrated by experiments. This should be of particular interest to those experimenting on the wireless transmission of images.

* * *

We are informed by the Honorary Secretary of the Radio Society of Great Britain that the British Broadcasting Company have agreed to allow a society transmission to take place once a week from their London broadcast station, which will be simultaneously transmitted to each of the provincial broadcast stations. It will thus be possible for notice of meetings, future policy, and matters of general interest to members and those associated with this Society to be broadcasted regularly. The time arranged is each Thursday evening at 7.25. The first transmission took place on October 11, when Dr. W. H. Eccles, F.R.S., president of the Radio Society, spoke. As this broadcast will be made from all stations in the British Isles, there should be no difficulty in all members picking it up.

* * *

The Radio Research Society has been formed expressly for serious experimenters and research workers in wireless and kindred sciences. Meetings are held at the British Red Cross (Camberwell Division), 44, Talfourd Road, Peckham Road, S.E., every Wednesday, at 7.30 p.m. The Hon. Secretary is Mr. A. H. Bird, 35, Bellwood Road, Waverley Park, Nunhead, S.E.15.

* * *

A broadcasting company is to be established in the Irish Free State with a capital of not less than £30,000. A station is to be erected in Dublin, with, possibly, relay stations at Cork and Limerick.

* * *

The licence problem has arisen in Ceylon. A Bill has just passed the Legislative Council which provides for the use by private individuals of wireless telegraphy, a privilege which has hitherto been restricted to the Government and the Admiralty. We understand that, so far, telegraphy only is being used; telephony and broadcasting developments may be looked for in the near future.

* * *

The invention of crystal "tablets" is attributed to Mr. George T. Gurr, of Fulham. Under this scheme crystals are broken down and then compressed into tablet form. Mr. Gurr claims that the tablets are simpler to mount, give complete contact, and can be replaced in exactly the same size. Incidentally, they are saidto be cheaper to produce

Business Brevities.

Two new books issued by the Wireless Press, Ltd., are "Time and Weather by Wireless," by W. G. W. Mitchell, B.Sc., F.R.A.S., price 3s. 6d. net, and "Wireless Telephony," by R. D. Bangay, price 2s. 6d. net. The former explains the system of time signals in official use, and how they are sent, and also how weather forecasts and reports are prepared and distributed by wireless. The latter is an excellent introduction to the electrical and physical phenomena occurring in wireless transmission and reception, followed by simple explanations of the working principles of apparatus in general use. We have also received from the same publishers "The Wireless Experimenter's Diary," price 2s. 6d., and "The Wireless Amateur's Diary," price 1s., both containing appropriate wireless matter in addition to the usual diary information and spaces.

* * *

Numerous reductions in prices are announced by the Grafton Electric Co., 54, Grafton Street, W.1. A sheet of nearly 100 price changes, and additions to their list No. 2 has reached us, many of the reductions ranging from 20 per cent. to 50 per cent.

* * *

Members of the National Association of Radio Manufacturers announce that they are prepared to credit their trade customers with the difference between the old B.B.C. tariff and the scale now in force in respect of sets in stock on October 1, 1923, to which the B.B.C. tariff applies. Trade buyers desiring to claim such credit must lodge the claim

with the respective suppliers of the sets on or before November 10, 1923, and should apply to their suppliers for the necessary forms of claim.

* * *

Ebonite accessories and materials for wireless are dealt with in a 4 pp. list received from the Hightensite and Ebonite Manufacturing Co., Ltd., Normandy Works, Customs House, E.16. A useful list for experimenters.

* * *

The "Morris" Valve Template is a simple device for enabling the holes for valve sockets or legs to be marked out quickly and accurately in one operation. It is supplied by Messrs. J. O. Nichol and Co., 46, Lancaster Avenue, Fennel Street, Manchester.

* * *

Readers who are experimenting with "Neon" lamps on the lines described by Mr. E. H. Robinson in our last issue will be glad to know that the General Electric Co., Ltd., can supply "Osglim" lamps fitted with standard caps but without resistances. These lamps can be obtained through the usual trade channels.

* * *

Messrs. George Philip & Son, Ltd., of 32, Fleet Street, London, E.C.4, send us a sample of an interesting instructional model in cardboard, illustrating and explaining the working of a two-valve receiving set. A rotating disc, behind a diagram of a 10-valve set brings into view supplementary portions of the diagram which show exactly what is happening in the circuit at various moments. The price of the model is 2s. 3d. They also send us a copy of Philips' Wireless Map of Great Britain, which shows at a glance the location of the principal wireless transmitting stations in the country and their call letters. An excellent adjunct to the amateur station.

* * *

A 48 pp. list of wireless apparatus components and materials has just been issued by the Scientific Supply Stores, 126, Newington Causeway, London, S.E.1. The list covers everything "from a loud speaker to an 8 B.A. screw."

* * *

No doubt all readers are familiar with the "Extraudion" valve which has been placed on the market by the "Economic Electric, Ltd.," of London. It will be remembered that the peculiarity is a curious shaped grid and anode. We understand that the valve has recently been redesigned, and we find that on test it behaves very well, a useful property being the low filament consumption.

* * *

"Cymosite" is the trade name of another crystal which has been sent to us for test, and we understand that supplies are now available. An interesting feature is that the crystal and special catswhisker are enclosed in a dust-proof envelope, thereby guarding against damage by dust and grease.

The Trend of Invention.

We summarise below the more important wireless inventions which have been disclosed during the month, special reference being made to those of immediate interest to the experimenter.

Elimination of Interference.

A number of patents have been taken out from time to time covering arrangements for the purpose of separating received signals from atmospherics and strong jamming signals which depend on receiving the jammed signals on two circuits, the outputs of which are combined in such a way that all but the required signals are balanced out. Most of these arrangements appear to be sound at first sight, but in actual practice one would be liable to get one's desired signal in both circuits so that the desired, as well as the undesired, signals will be balanced out in the receiver. A method of preventing this happening is the subject of a voluminous specification of a patent recently granted to J. B. Bolitho (Brit. Pat. 202,700). Briefly, Bolitho's arrangement consists in coupling two H.F. amplifiers to one aerial, one amplifier being tuned and adjusted to respond to the weak signal which it is required to receive, the other amplifier being adjusted to respond only to the loud jamming signals. The latter condition can be attained by adjusting the grid-potentials on the second amplifier to a negative value sufficient to bring the operating points of the valves in this amplifier low enough on their characteristic curves to make the amplifier un-

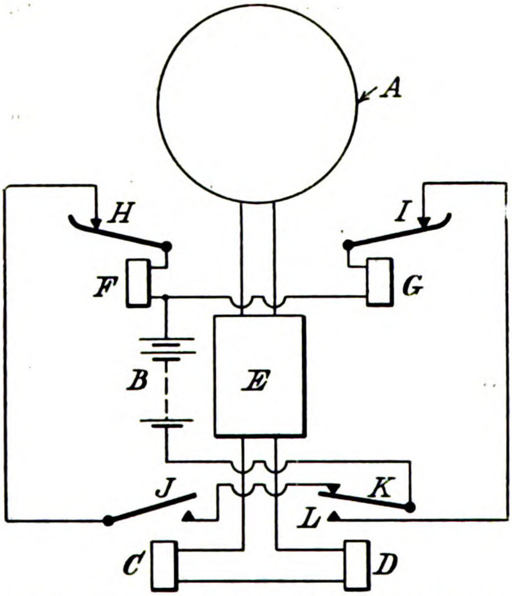


Fig. 1.—Scheme for self-aligning D.F. aerial described in British Patent Specification 202,733.

responsive to signals below a pre-determined amplitude. Thus, from the two amplifiers are obtained two sets of signals, one containing required signals plus jamming signals, and the other containing jamming signals only; by suitably superimposing these two sets of signals so as to oppose each other in some indicating device everything but the desired signal may be materially reduced. The specification describes various modifications of this system, and also arrangements for controlling the relative phases and waveforms of the different sets of signal currents before their combination is effected. The whole scheme is rather reminiscent of Round's balanced crystals, although elaborations and refinements are introduced which are scarcely anticipated by Round's patent.

Self-Orientating Loop Aerial.

Patent 202,733 (J. Robinson, H. L. Crowther and H. Derriman) describes a combination of relays and electro-mechanical devices with a rotatable loop aerial which, when the loop is tuned to a given signal will automatically cause the loop to rotate until the received current in the loop is a minimum, when the bearing reading may be taken. The adjustment is, therefore, not dependent upon the operator's estimate of audibility. Fig. 1 is a diagrammatic representation of one form of the invention. A is a loop aerial capable of revolution about a vertical axis. Received currents, after suitable amplification at E, energise the relays C and D, which in turn control the two magnetically-operated pawls H and I, which engage with ratchet wheels fixed to the axis of the loop aerial. Actual details of operation are given in the specification, along with modifications for automatically adjusting other types of D.F. aerial, including the one employing two loops fixed at right angles to each other.

Economical Production of Telephone Magnets.

The usual practice in making telephone earpieces has hitherto been to make the permanent magnet a separate stamping and to clamp on separate pole-pieces. The novelty in the stamping shown in Fig. 2 lies in the staggered shape, which permits the magnet and pole-ends to be stamped out of the same piece of metal. The patent covering this form of construction also covers other forms of stamping attaining the same object. (S. G. Brown, Brit. Pat. 203,121.)

Insulation of Water-cooled Anodes.

In valves having metallic water-cooled anodes (such as the type described in Brit. Pat. 190,184) provision must be made that

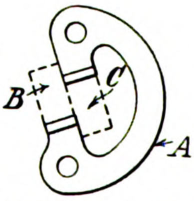


Fig. 2.—By stamping out telephone magnets as shown, and bending up the dotted portions, the construction of separate pole-pieces is avoided.

the water supply does not short-circuit the high-tension anode supply to earth. Such a provision is the subject of British Patent 185,753 (British Thomas-Houston Co., Ltd.), which covers the use of sufficiently long supply pipes to ensure that the column of water in them will have enough resistance to prevent the by-passing of the H.T. to any appreciable extent. In one particular arrangement described in the specification the supply and exhaust water tubes are made

of non-conducting material and wound side by side as a spiral on a large insulating cylinder placed outside and concentric with the anode. The upper ends of the two tubes forming this double spiral are in connection with the water jacket surrounding the anode.

Loud Speaker Construction.

Loud speakers with large conical diaphragms and no trumpets seem to have been attracting the attention of several inventors

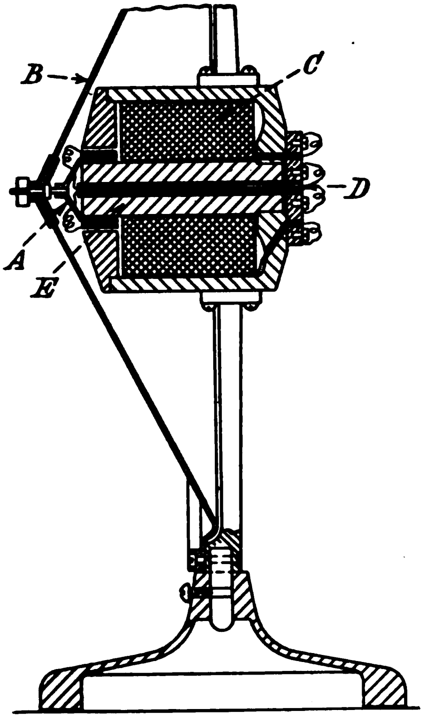


Fig. 3.—A loud speaker in which a large conical diaphragm is used, and the conventional horn dispensed with.

lately. Fig. 3 illustrates the mechanism of one such loud speaker (British Patent 178,862, C. L. Farrand and W. H. Davis). The polarising windings C are contained in an iron case, which also forms a completion for the magnetic circuit. Attached to the apex of the conical diaphragm B is a light coil A, which embraces, but does not touch, the central pole-piece E. The signal currents that are to actuate the loud speaker are passed into this coil A *viâ* wires brought out to terminals at D. It will be seen that the movement depends upon the solenoid principle. The diaphragm A is supported at its periphery. One of the specific features of the invention is that the electro-magnetic system is housed in the concavity of the diaphragm.

Valve Construction.

Fig. 4 illustrates a patent covering the grid used in the well-known C.V.C. valve (British Patent 203,097, W. R. Bullimore). The construction will be familiar to most readers, one of its objects being to make the grid mechanically rigid with respect to the filament and thus to avoid microphonic noises. The specification describes one or two slight modifications of the construction illustrated here.

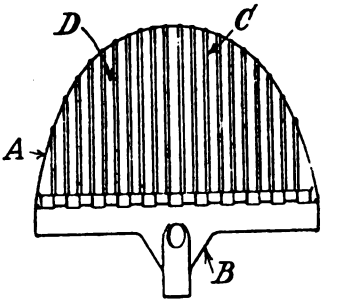


Fig. 4.—Illustrating the Cossor grid.
Keying a Magnetron Oscillator.

Keying a Magnetron Oscillator.

British Patent 199,038 (British Thomson-Houston Co., Ltd.) covers a method of controlling the output of a magnetron oscillator (such as is claimed in British Patent 169,889). Fig. 5 shows a magnetron circuit, the magnetron tubes V1 and V2 each containing only a filament and an anode, the reaction control being effected magnetically by the external coils D and E. An independent set of coils F, fed by battery B, contains the key. The strength of this independent magnetic field may be such as to reduce the anode current in the magnetrons to zero. G is the H.T. generator and T the filament lighting transformers.

Modified Beverage Aerial.

The Beverage aerial in its simplest form consists of a long single wire with a tuned receiver at one end, the remote end being earthed through a system of ohmic, inductive and capacitative impedances so adjusted as to avoid reflection of incident waves at the remote end. In practice it is rather awkward to have to make adjustments at both ends, and an ingenious scheme has been

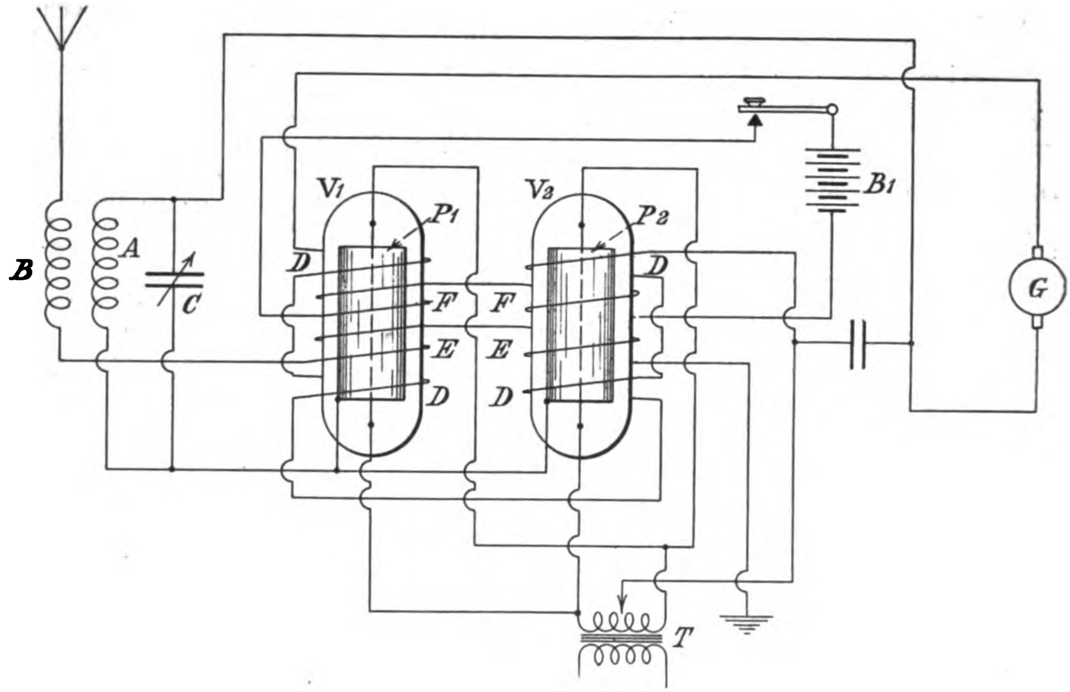


Fig. 5.—Keying a magnetron by means of an auxiliary field excited by D.C.

devised whereby all circuits requiring adjustment are brought to one end. The basic principle, covered by British Patent 192,346 (British Thomson-Houston Co., Ltd.), lies in the employment of two parallel wires instead of one combined with special transformer arrangements at each end, which allow the two wires to act in parallel as far

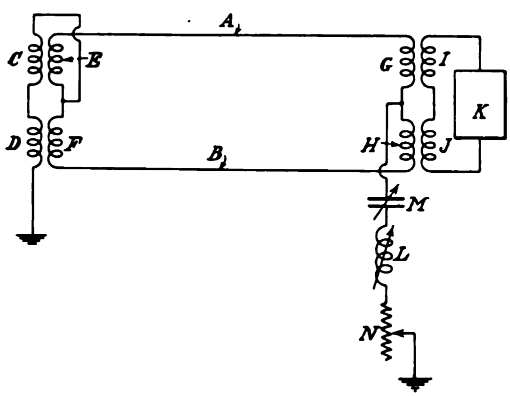


Fig. 6.—Modified Beverage aerial in which all adjustable members are brought to one point by the use of the "phantom circuit" principle.

as the incident ether waves are concerned, but to act in series as a "land-line" as far as the signal currents are concerned. British Patent 203,446, which is illustrated in Fig. 6, covers modifications allowing the receiver to be introduced at either end or any intermediate point in the aerial. The windings E and F are mutually non-inductive, but are inductively coupled to the windings C and D; hence, a wave travelling in the same direction with respect to A and B induces current by virtue of the transformers C, E and D, F, which circulate round the path E, F, G, H. The windings G, I, H and J act in a similar manner. The receiver K thus is affected by currents set up in the remote windings C and D. M, L and N are normally adjusted to have an impedance equivalent to the surge impedance of the aerial A, B in order to prevent wave reflection at the end G, H. It is stated, however, that a certain amount of reflection is sometimes desirable. The specification describes arrangements by means of which the receiver K may be introduced at a point intermediate between the extremities of the aerial.

Rapidly Adjustable Crystal Detector.

A tube E (Fig. 7) is supported between two pillars A, and in it the two crystals D are held in contact by plungers on the end of rods B and C. One plunger has a screw adjustment, while the other maintains a resilient pressure between the crystals by means of a spring. External connections are made to the plungers. (British Patent 203,517, H. P. P. Rees.)

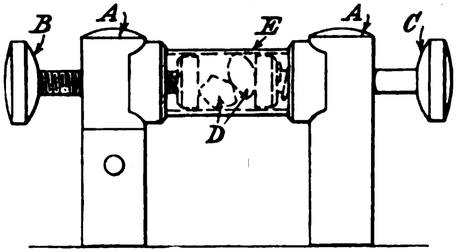


Fig. 7.—Construction of an adjustable enclosed crystal detector.

Recent Wireless Publications.

Figures after the title of each publication indicate Volume and Number of Publication containing the article. Where only one number is given, this indicates the serial number of the publication.

ABBREVIATIONS OF TITLES OF JOURNALS USED IN THE BIBLIOGRAPHY.

Amer. Acad.—American Academy of Arts and Sciences.
Am.I.E.E. J.—Journal of American Institute of Electrical Engineers.
Ann. d. Physik—Annalen der Physik.
Boll. Radiotel.—Bolletino Radiotelegraphico.
Elec. J.—Electric Journal.
El. Rev.—Electrical Review.
El. Times—Electrical Times.
El. World—Electrical World.
Electn.—Electrician.
Frank. Inst. J.—Journal of the Franklin Institute.
Gen. El. Rev.—General Electric Review.
Inst. El. Eng. J.—Journal of the Institute of Electrical Engineers.
Inst. Rad. Eng. Proc.—Proceedings of the Institute of Radio Engineers.
Jahrb. d. drahtl. Tel.—Jahrbuch der drahtlosen Teleg, etc.
Mod. W.—Modern Wireless.
Nature—Nature.
Onde El.—L'Onde Electrique.
Phil. Mag.—Philosophical Magazine.
Phil. Trans.—Philosophical Transactions.
Phys. Rev.—Physical Review.
Phys. So.. J.—Journal of Physical Society of L.n on.
Q.S.T.—Q.S.T.
R. Elec.—Radio Electricité.
Roy. Soc. Proc.—Proceedings of the Royal Society.
Sci. Abs.—Science Abstracts.
T.S.F.—Telegraphie sans fils, Revue Mensuelle.
Teleg. without Wires, Russia—Telegraphy without Wires, Nijni Novgorod.
W. Age—Wireless Age.
W. Trader—Wireless Trader.
W. World—Wireless World and Radio Review.

I.—TRANSMISSION.

LA STATION RADIOPHONIQUE DE LA VILLE DE LAUSANNE.—G. Lepot, Ingénieur E.S.E. (*R. Elec.*, 4, 12).

EIN TELEFUNKENSENDER FÜR DEN UNTERHALTUNGS RUNDSPRUCH.—(*Telefunken Zeitung*,).

TRANSOCEANIC RADIO TELEGRAPHY.—E. F. W. Alexanderson (*W. Age*, 10, 12).

EFFICIENT TRANSMISSION.—F. L. Hogg (*Exp. W.*, 1, 1).

JAPANESE-AMERICAN RADIO CIRCUIT.—C. W. Latimer (*Am.I.E.E.*, 42, 10).

II.—RECEPTION.

SHORT WAVE-LENGTH HIGH-FREQUENCY AMPLIFICATION.—W. James (*W. World*, 214).

DISTORTION IN LOW-FREQUENCY AMPLIFIERS.—S. O. Pearson, B.Sc. (*W. World*, 216).

A PORTABLE ARMSTRONG "SUPER."—W. Winkler (*W. World*, 216).

DISTORTIONLESS TELEPHONY RECEPTION.—F. H. Haynes (*W. World*, 217).

DISTORTION IN LOW-FREQUENCY AMPLIFIERS (*concluded*).—S. O. Pearson, B.Sc. (*W. World*, 217).

BUILDING A THREE-VALVE RESISTANCE COUPLED AMPLIFIER.—F. H. Haynes (*W. World*, 218).

A SIMPLIFIED METHOD OF NEUTRALISING VALVE CAPACITY IN RADIO-FREQUENCY AMPLIFIERS.—(*W. World*, 218).

THE VALVE FOR THE MAN IN THE COUNTRY.—R. W. Hallows, M.A. (*Mod. W.*, 2, 1).

AN ULTRA SELECTIVE CIRCUIT.—F. L. Hogg (*Exp W.*, 1, 1).

SOME NOTES ON DISTORTIONLESS AMPLIFICATION.—Paul D. Tyers (*Exp. W.*, 1, 1).

Some Useful Long-wave Circuits.—G. P. Kendall, B.Sc. (*Mod. W.*, 2, 1).

A Demonstration of a Novel Instrument for Record Wireless Signals.—N. W. McLachlan, D.Sc., M.I.E.E. (*Phys. Soc. Proc.*, 35, 5).

The Freeman Counter E.M.F. Receiver.—Dr. A. E. Banks (*W. Age*, 10, 12).

The How and Why of Crystal Detectors.—J. Snyder (*W. Age*, 10, 12).

Physical Measurements of Audition and Their Bearing on the Theory of Hearing.—Harvey Fletcher (*Frank. Inst. J.*, 196, 3).

The Effect of Valve Capacity in H.F. Coupling.—P. K. Turner (*W. Trader*, 1, 8).

Das Gleichzeitige Auftreten Atmosphärischer Störungen.—M. Bäumler (*Jahrb. d. drahtl. Tel.*, 22, 1).

Uber die Störungsfreiheit der Empfänger der drahtlose Telegraphie.—A. Koerts (*Thesis, Utrecht, Holland*, 1922).

Un Apparechio di Registrazione Automatica dei Segnali Radiotelegrafici, Regia Accademia Navale-Livorno.—Guiseppe Pession (*Publicazione dell' Istitute Elettrotecnico e Radiotelegrafico Della R. Marina*, No. 19, 1922).

The Fading of Signals.—O. F. Brown, M.A., B.Sc. (*Exp. W.*, 1, 1).

The Design and Operation of Tuned Anode Receivers.—Capt. St. Clair-Finlay, B.Sc.E. (Laus.) (*Exp. W.*, 1, 1).

Crystals and Crystal Testing.—A. V. Ballhatchet, M.J.I.E. (*Exp. W.*, 1, 1).

An Armstrong Super-Heterodyne Receiver.—E. J. Simmonds (*Exp. W.*, 1, 1).

Radio-frequency Amplification.—Louis Frank (*Radio News*, 5, 4).

The Galena Loud Talker.—Clyde J. Fitch (*Radio News*, 5, 4).

III.—MEASUREMENT AND CALIBRATION.

A Simple Method of Coil Calibration.—Gerald R. Garratt (*W. World*, 217).

The Rapid Measurement of High Resistances with the Neon Lamp.—A. D. Cowper, M.Sc. (*Mod. W.*, 2, 1).

The Calculation and Measurement of Inductance.—(*W. Age*, 10, 12).

La Constuction d'un Ondamètre Portatif pour Petites Longueurs d'Ondes.—(*Onde El.*, No. 14, 1923).

Antenna Constants.—H. Andrewes, B.Sc., A.C.G.I., D.I.C. (*Exp. W.*, 1, 1).

IV.—THEORY AND CALCULATIONS.

La Vibration des Antennes.—(*R. Elec.*, 4, 12).

Pertes dans les Antennes aux Faibles Longueurs d'Onde.—W. Sanders (*R. Elec.*, 4, 13).

Forced Oscillations in Self-maintained Oscillating Circuits.—(*Phil. Mag.*, 274).

Uber labile Röhrenschwingungen und Schwebungen in gekoppelten Kreisen.—K. Heegner (*Jahrb. d. drahtl. Tel.*, 22, 2).

V.—GENERAL.

Investigations on Some Valve Circuits with the Cathode-Ray Oscillograph.—N. V. Kipping (*W. World*, 214).

An Easy Method of Winding Honeycomb Coils.—R. O. Challis (*W. World*, 215).

A New System of Duplex Telephony.—H. N. Ryan (*W. World*, 215).

Testing High-frequency Transformers.—Maurice Child (*W. World*, 216).

The Amateur's Part in Wireless Development.—W. H. Eccles, F.R.S., D.Sc. (*W. World*, 217).

The Broadcasting Report (*W. World*, 217).

Home-made Inductance Coils of Low Distributed Capacity.—Victor Gabel (*W. World*, 218).

Variometers.—W. James (*W. World*, 218).

Un Gigantesque Laboratoire d'Etudes de la Propagation des Ondes.—(*R. Elec.*, 4, 12).

A Propos de l'Invention de la T.S.F.—J. Bethnod (*R. Elec.*, 4, 12).

Une Nouvelle Telegraphie sans Fil sous-marine.—Michel Adam, Ingénieur E.S.E. (*R. Elec.*, 4, 12).

Les Origines de la T.S.F.—Daniel Berthelot (*R. Elec.*, 4, 13).

Le T.S.F. en Amerique de Sud.—M. R. Belmere (*R. Elec.*, 4, 13).

Une Nouvelle Exploration Hertzienne.—E. Pepinster, Ingénieur E.C.P. (*R. Elec.*, 4, 13).

Les Radiotelegrammes Sismologiques.—(*R. Elec.*, 4, 13).

Single and Duplex Basket Coils.—E. R. Gilbert (*Mod. W.*, 2, 1).

Drahtlose Telephonie Amerika-Europa.—(*Telefunken Zeitung*).

Die Entwicklung der Radiotelephonie durch Telefunken.—(*Telefunken Zeitung*).

Recent Developments in the Application of Wireless Telegraphy to Shipping.—Capt. J. A. Slee (*El. Rev.*, 2,391-2,392).

Duplex Radio Telephony.—(*El. Rev.*, 2,393).

Recent Developments in the Application of Wireless Telegraphy to Shipping.—Capt. J. A. Slee (*Electn.*, 2,369).

Radio Extensions of the Telephone System to Ships at Sea.—H. W. Nichols and Lloyd Espenschied (*Electn.*, 2,369).

Transatlantic Radiotelephony.—H. D. Arnold and Lloyd Espenschied (*Electn.*, 2,370).

On Ionic Oscillations in the Striated Glow-Discharge.—R. Whiddington (*Phil. Mag.*, 274).

Wireless Direction Finding in Steel Ships.—C. E. Horton (*Inst. El. Eng. J.*, 61,322).

Antennen mit Vielfach-Erdung.—P. Bouvier (*Jahrb. d. drahtl. Tel.*, 22, 1).

Der Creedsche Schnelltelegraph.—P. Lertes (*Jahrb. d. drahtl. Tel.*, 22, 1).

Sekundäre Electronenemission Glühcathodenröhren.—A. Goetz (*Physikal Zeitschr.*, 24, 2).

Uber die Herstellung kleiner Wechselspannungen von bekannter Amplitude.—H. G. Möller and E. Schrader (*Jahrb. d. drahtl. Tel.*, 22, 2).

Der Creedsche Schnelltelegrap (*concluded*).—P. Lertes (*Jahrb. d. drahtl. Tel.*, 22, 2).

The Maintenance of High-frequency Oscillations.—E. W. B. Gill, M.A., B.Sc. (*Exp. W.*, 1, 1).

Pioneer Work in Ether Waves.—Sir Oliver Lodge, D.Sc., LL.D., F.R.S. (*Radio News*, 5, 4).

Construction of Push-Pull Transformers.—(*Radio News*, 5, 4).

Neon Lamps and Their Use for Wireless Purposes.—E. A. Robinson (*Exp. W.*, 1, 1).

Experimental Wireless

A JOURNAL OF RADIO RESEARCH AND PROGRESS

VOL. I, No. 3. DECEMBER, 1923. 1s. NET.

Experimental Topics.

Wireless Television.

IN the course of an address given before the Royal Society of Arts last month M. Edouard Belin disclosed the fact that he had recently succeeded in transmitting real photographs in half-tones by wireless. M. Belin has been making extended researches in his laboratory at La Malmaison, and he is convinced that the solution of the problem of wireless television is near at hand. The Belin system of telephotography had been developed not only to permit of the transmission of ordinary handwriting and of shorthand, but also to provide absolute secrecy in telegraphic and radiotelegraphic transmissions. Autograph messages have been transmitted by wireless both in France and America. This is a fascinating field of research, and it does not require much imagination to visualise the enormous possibilities of wireless television when achieved on a commercial scale.

The Wireless Exhibition.

The All-British Wireless Exhibition at Shepherd's Bush which has formed the centre of radio interest during the middle fortnight of November came exactly at the right moment. The Postmaster-General, by his recent licensing decisions had cleared the way for a revival of business, and a large section of the public, fortified by the knowledge that they had made their peace with the law, or could do so quite easily at the nearest post-office, flocked to see the latest developments in British wireless practice. In one respect the crowd was very different from that which thronged last year's Exhibition at the Royal Horticultural Hall. It was a much better informed crowd. Last year the attendants at every stand in the show were bombarded with requests for explanations of how "it was done." This year the crowd came armed with knowledge: questions of an elementary nature were much less in evidence, and reasoned praise or criticism of construction and design much more general. This is all for the good of wireless, and the Exhibition itself has undoubtedly still further advanced the education of the radio public. The Exhibition, taken as a whole, was a very representative display, though broadcasting interests certainly predominated and some very fine examples of complete receiving installations moved one critic to describe it as being more of a cabinet-making than a scientific exhibition. This is not altogether an unfair comment for the time is within sight when every well-appointed home will have a receiving equipment *en suite* with the rest of the furniture, just as it now includes a book-case, or a sideboard, or a piano. From the experimenter's point of view the outstanding feature of interest was the display of dull-emitter valves by various makers, although there were many firms showing other components and accessories worthy of close attention. Elsewhere in this issue we deal in some detail with the

more interesting items which came to our notice; it is outside our province to attempt a complete description of all the exhibits, and we have contented ourselves with commenting on those matters of especial interest to experimenters. We would add our congratulations to the National Association of Radio Manufacturers, and to Mr. Bertram Day, on the success of the Exhibition, and hope that it has given to the wireless trade in general an impetus which was very badly needed.

The Transatlantic Tests.

This year the Transatlantic Tests organised in conjunction with the American Radio Relay League are due to commence on December 22. Although many experimenters occupy their time with Transatlantic work throughout the greater part of the winter, the official tests always arouse considerable interest amongst amateurs as a whole, and it is anticipated that the number of listeners on this side will be greatly increased by many newcomers in the field of experimental work. To those we make a special appeal. The radiating properties of a receiving aerial on 200 metres are very good, and unless particular care is exercised in the use of oscillating circuits, it is highly probable that the work of an experienced experimenter may be completely spoiled by radiation from a neighbouring aerial. In the subsequent pages of this issue will be found several articles particularly relating to short-wave reception, and it is sincerely to be hoped that many will adopt the suggestions given, to the benefit of all concerned. So far as our own transmission is concerned, the granting of 100 and 1,000-watt licences to certain experimenters certainly increases our chances of "getting across the pond," but the ultimate success of the experiment is, unfortunately, wholly dependant upon the prevailing conditions during the period of the tests.

Very Variable Condensers.

We publish in our correspondence columns this month a letter from a reader who complains of the unsatisfactory state of affairs in the trade in regard to the capacity rating of variable condensers. While it is true that there are firms to whom our correspondent's criticisms do not apply, we think it is equally true that there are good grounds for complaint in other directions It is easy to see the harm which may be caused to the wireless industry by the sale of unreliable or of mis-represented goods; the disappointed constructor or experimenter may prove to be a very bad advertisement for wireless in general, and for unreliable firms in particular. Possibly the trouble complained about arises in some cases from want of thought, or from the lack of real technical knowledge, on the part of the vendor. A good many people have rushed into the wireless business with only a slight smattering of the science underlying the apparatus they sell, and they do not altogether appreciate the need for something more than approximate accuracy in their instruments or in their descriptive matter. Day by day wireless is becoming more and more of an exact science, and indeed one has only to move among the best firms in the trade to realise how much true scientific knowledge and research is being applied to the advancement of the industry. It is important that the lesser firms too should realise the need of putting their products on a sound basis of scientific accuracy, and the importance of making impossible such criticism as our correspondent expresses in the letter we have referred to.

Our Progress Abroad.

We are glad to be able to report that EXPERIMENTAL WIRELESS is making friends with wireless workers overseas just as readily as at home. Although the time for the receipt of return mails has in many cases barely elapsed, we have already received subscriptions and letters of congratulation from experimenters in the United States, Brazil, South Africa, Switzerland, France, Portugal, Austria, Belgium, Holland, Germany, and Egypt. Some of our correspondents have promised us notes on experimental equipment and methods in their own countries, and this friendly co-operation coupled with other arrangements for overseas information we have put in hand will ensure for our readers that international exchange of experience and knowledge which is essential for the advance of every branch of science. Our readers may be interested to know that one letter we received during the past few days from Germany carried twenty-one postage stamps, each of the value of two thousand million marks!

Directive Radio Telegraphy and Telephony.

By R. L. SMITH-ROSE,* Ph.D., M.Sc., D.I.C., A.M.I.E.E.

During the last few years there has been considerable development in directional work, particularly with the use of extra short waves. There are obviously many applications of directional transmission, and we are giving below a general summary of modern methods and practice.

I.—THE EMPLOYMENT OF SHORT WAVES UP TO ABOUT 20 METRES IN LENGTH.

(a.) Early Experiments of Hertz and Marconi.

THE classical experiments of Hertz carried out from 1885 onwards are now known as verifying the predictions of Maxwell's electro-magnetic theory. These experiments of Hertz* demonstrated

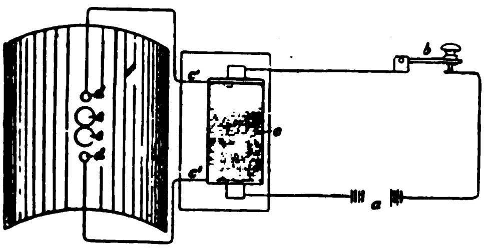


Fig. 1.—An early short wave directional transmitter.

the essential properties of the waves which are created by the electrical discharge of a condenser, these properties being exactly similar to those of the much shorter waves commonly associated under the terms light and heat. The means for the production of the waves was found in the type of open oscillator developed by Hertz, a similar open oscillator or a nearly closed ring resonator being used for reception purposes. The waves generated were shown to penetrate through bodies which are generally classed as dielectrics, and to be subject to refraction in such transmission, the angle of refraction being found to agree with that calculated from the usual optical formula, using the appropriate values for the refractive indices of the media traversed. Other bodies classed as conductors were shown to be opaque to the radiation, this being completely reflected from metallic surfaces. The superposition of the reflected waves from a metallic surface on the incident waves was shown to give rise to a set of stationary waves, which proved the finite velocity of travel of the waves and also provided a means of determining the length of the waves in air. The wavelengths used by Hertz and other workers at that time were of the order of 1 or 2 metres down to a few centimetres.

By arranging the reflector in parabolic form, with its axis parallel to the oscillator employed, the radiation could be concentrated in a roughly parallel beam for projection in any desired direction, and a similar reflector at the receiving end served to concentrate the radiation on the detecting instrument placed at the focus. The radiation so produced was shown to be plane polarised with the electric force parallel to the oscillator, and experiments were carried out by Hertz with wire grid screens which are exactly analagous to the transmission and absorption of polarised light by Nicol prisms.

Many scientific workers were immediately attracted to Hertz's discoveries, but the majority of these were chiefly concerned with the researches opened up by the demonstration of the electro-magnetic nature of luminous radiation and the corresponding development of optical theories. Other workers concentrated their attention on the production of a more efficient generator of the waves, and a more sensitive and reliable detector of the oscillations produced at the receiving end. Confining our attention, however, to directive radiation, it appears that Marconi was the next to make any use of reflectors for the concentration of waves in the required direction in about

* H. Hertz, "Electric Waves," translated by D. E. Jones, 1900, p. 172.

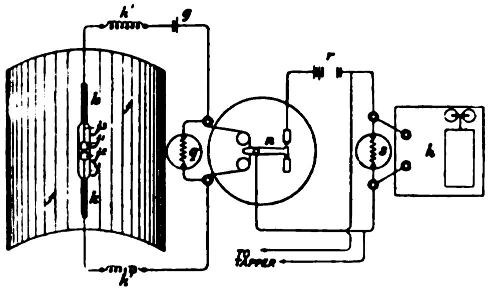


Fig. 2.—An arrangement comparable with Fig. 1, adapted for reception.

1895*. The general plan of the transmitting and receiving apparatus is shown by Figs. 1 and 2. An induction coil *c* (Fig. 1) was used to charge the spheres *d*, *e* of a Righi oscillator placed in the focal line of a suitable cylindrical parabolic reflector, *f*. On pressing the key *b* an oscillating discharge occurs across the system of spheres which thus become the source of radiated waves. At the receiving end, two short conducting strips *k* are placed in the focal line of a similar reflector *f*, connected to a filings coherer *j*, which acting as a detector on the arrival of waves caused the operation of the relay *n* and the recorder *h*. The length of the copper strips *k* was carefully determined to be in tune with the transmitted waves.

By means of apparatus of this description Marconi was able to transmit intelligible signals over distances up to 1¾ miles, and the concentration of the beam was such that, at this distance, its effective width in which the receiver could be operated was only 100 feet. Marconi immediately appreciated most of the advantages to be derived from the directional selectivity accompanying this arrangement and the possible application of a rotating wireless beacon as an aid to ship navigation in a similar manner to the use of lighthouses. Owing, however, to the greatly increased signalling range which was obtainable by earthing one side of the Hertzian oscillator and extending the other as a long vertical wire up to 100 feet in height, further experiments on the use of the reflecting system were discontinued. At that time the development of the subject was being concentrated upon its application to communication over the greatest distances possible, and with the generating apparatus then available this was found to be most easily accomplished by the use of elevated antennæ at both transmitting and receiving ends. Now the application of optical principles shows that in order that the parabolic metal sheet should act as a reflector its length must be equal to several times the length of waves employed and the focal distance should be not less than one-quarter of a wave-length. Hence, in order that the reflector system shall be practicable, particularly if the reflector is to be used to give a revolving beam, the length of waves employed must be limited to a few metres,

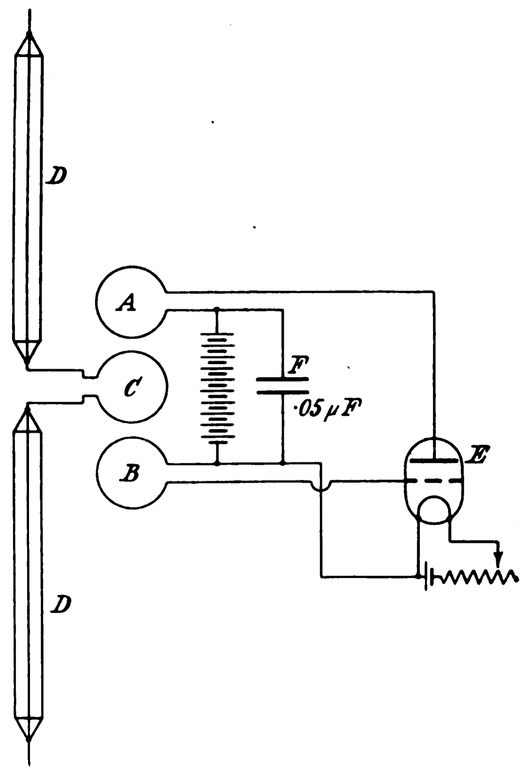


Fig. 3.—A short wave generator in which the inductances take the form of single turns, inductively coupled to the aerial system

whereas those emitted by the elevated antennæ ranged from 50 metres upwards. Research on the utilisation of the waves for the continued extension of the range for

* G. Marconi, "Wireless Telegraphy," *Journal I.E.E.*, 1899, Vol. 28, p. 273; G. Marconi, "Radio Telegraphy," *Proc. Inst. Radio Eng.*, 1922, Vol. 10, p. 215.

transmitting purposes led to the use of increasingly longer waves, up to the present-day limits of about 20 kilometres, which, apart from being subject to less absorption by the atmosphere and surface of the earth, were much more easily generated in the higher powers necessarily involved. Also the first practical application of wireless, namely, for communication to and between ships, demanded "all round" transmission rather than a directional system. This aspect of the reflector system was apparently so discouraging that, except for the filing of one or two patents covering the use of separate vertical wires in place of sheet metal for the reflector, no research work of any description was carried out on short wave propagation between 1896 and 1916.

(b.) Recent Work of Marconi and Franklin.

In the latter year experimental work in this direction was resumed by Senatore Marconi, assisted by Mr. C. S. Franklin,* the waves employed being 2 or 3 metres in length. Preliminary experiments showed that on these short wave-lengths one of the great difficulties in modern wireless telegraphy, *viz.*, interference, is very greatly reduced. The only source of interference apparent was that due to the ignition systems of motor cars and motor boats in the vicinity, which emit waves of from 1 to 40 metres in length. Similar difficulties were experienced at the introduction of wireless reception on aeroplanes, and the remedy there adopted was to efficiently screen the whole of the ignition system.

The early experiments showed that the use of reflectors considerably increased the working range of the apparatus for communication purposes, and good directive properties were also obtained with reflectors properly proportioned to the wave-length. With the waves of 3 metres length used in some experiments at Carnarvon the attenuation was found to be very great even over sea, and the range of transmission was correspondingly limited to about 4 to 6 miles. The strength of the electric field, however, increases with the height above the ground at a rate dependent on the wave-length, and, although with the long waves commonly employed this is not perceptible, the increase is very rapid with short waves. Franklin found, for example, that by raising transmitter and receiver to a height of about 10 wave-lengths above the intervening ground the range could be increased to six or seven times its former value.

The usual arrangement of these directional transmitters is in the form of a single Hertzian rod placed vertically in the focal line of a cylindrical paraboloid reflector. The rod is coupled by a single turn loop at its centre to an oscillating valve circuit, which while

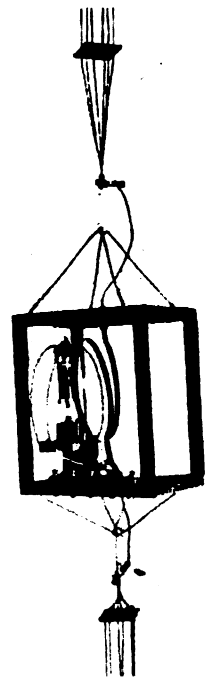


Fig. 4.—Illustrating the method of using the oscillator shown in Fig. 3.

of quite the usual form has very small electrical constants for the extremely high frequency required. Quite frequently the interelectrode capacity of the valve is sufficient for a circuit whose inductance comprises a single turn loop of a few inches. Such a generator is shown in Figs. 3 and 4, taken from a Bureau of Standards paper* in

* C. S. Franklin, "Short-Wave Directional Wireless Telegraphy," *Journal I.E.E.*, 1922, Vol. 6, p. 930.

* F. W. Dunmore and F. H. Engel, "Directive Transmission on a Wave-length of 10 Metres," *Bureau of Standards Scientific Paper No.* 469, 1923.

which sufficient details are given to enable construction to be carried out. The reflector is formed of a framework supporting a number of straight vertical wires around its surface (Fig. 5). The length of the individual wires is adjusted to bring them in resonance with the wave-length in use, the length of the wires being usually somewhat less than half a wave-length owing to the mutual capacity between them. The effect of alteration in the length of wires on the polar radiation curves is shown in Figs. 6 and 7.

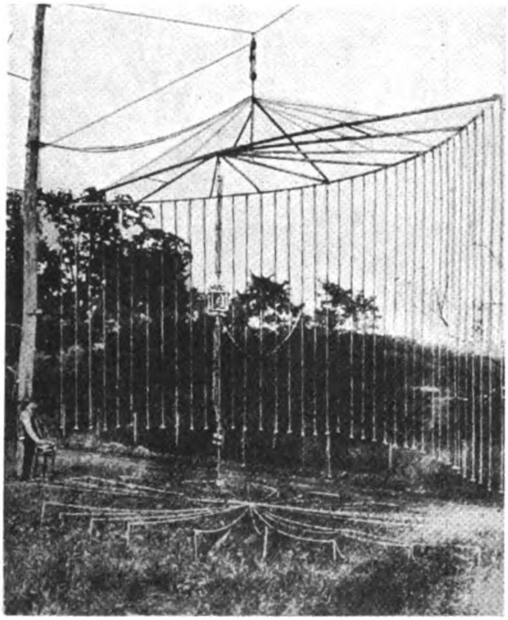


Fig. 5.—A parabolic reflector for a wavelength of 10 metres.

In the case of Fig. 6 all the wires have been carefully adjusted in length to be in tune with the waves. In Fig. 7 alternate wires have been removed from the screen, and owing to the resulting decrease in mutual capacity the remaining wires are now slightly out of tune and some radiation is now seen to be transmitted behind the screen.

For reception, either a loop or another rod oscillator may be employed suitably adjusted to the wave-length, and of course with the straight rod a parabolic reflector may again be used to concentrate the received energy on the rod.

(c.) Application of Reflector Systems to Communication.

One of the uses to which this directional transmission has been put experimentally by the engineers of the Marconi Company is that of radio telephony. Since in the employment of a rod oscillator with reflector a fairly concentrated beam of radiation is produced, it is evident that no wireless receiver placed outside the beam will receive any signals whatever. Within limits the "spread" of the beam can be reduced by increasing the aperture of the reflector as shown in Fig. 8. This, combined with the great difficulty of tuning a receiver to such a short wave-length when this is not accurately known, makes the system very much more secret for telephonic purposes than the ordinary broadcast mode of transmission. Tests carried out over both sea and land show this short-wave reflector system of radio telephony to be quite practicable at distances up to about 100 miles on a wave-length of 15 metres. In some of Franklin's experiments carried out between Hendon and Birmingham in 1921, local measurements of the polar curves taken round the station show that the electric field is increased about four times and that the same order of increase is obtained during reception. The increase of energy due to each reflector will, therefore, be sixteen times, giving a total increase of 256 with reflectors at each end. This calculated figure agrees well with actual measurements made with the reflectors both up and down. By using two medium-size power valves in parallel receiving about 700 watts input, about 300 watts radiated power could be obtained. To get the same signal strength without the use of reflectors would require a 140-kw. transmitter working at the same efficiency. Although the frequency of 20 million cycles per second gives rise to some problems in the structure and operation of the valves employed, there appears to be no reason why input powers of several kilowatts may not be used in such a system.

(d.) The Revolving Wireless Beacon.

Reverting now to the directional properties of the reflector systems, the general idea is to use a revolving beam transmitter as a kind of wireless lighthouse. The beam will be invisible, but if a suitable receiver be

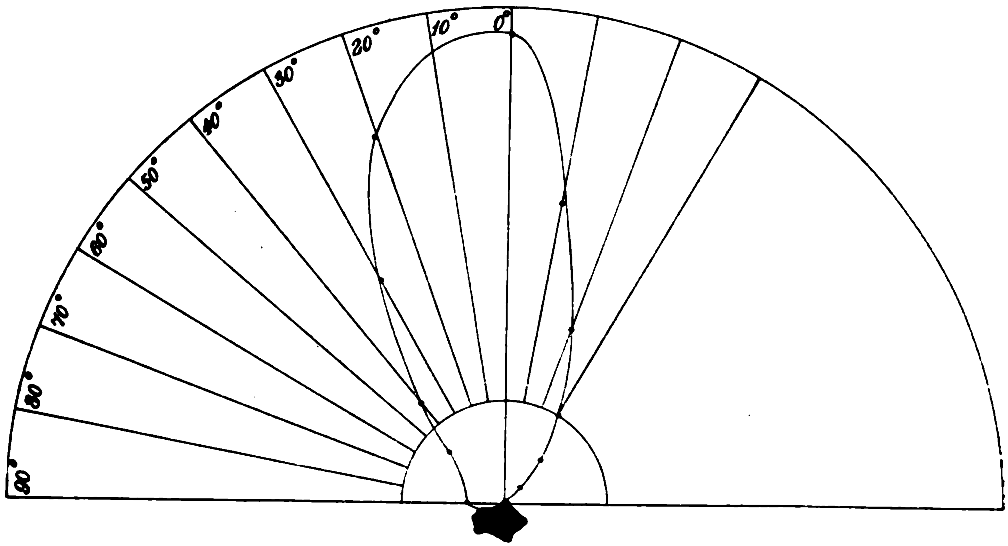


Fig. 6.—The Radiation Characteristic Curve of a parabolic reflector when the aperture is equal to one wave-length. The deflecting wires are all in tone with the source.

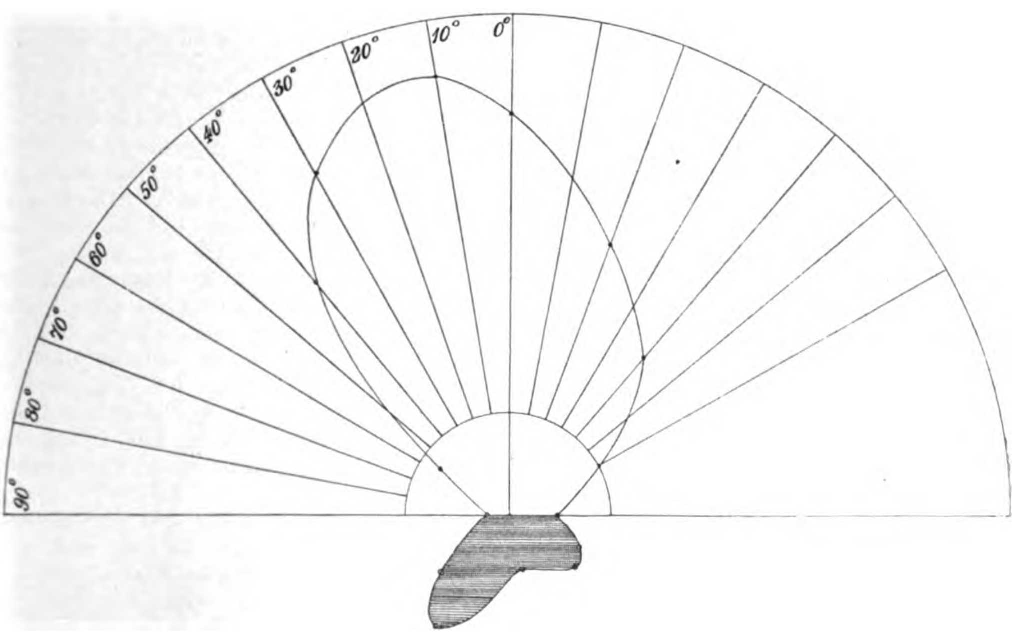


Fig. 7.—The Radiation Characteristic Curve of a parabolic reflector when the aperture is equal to one wave-length (10 metres), but with every other reflecting wire removed, the remaining twenty wires being detuned.

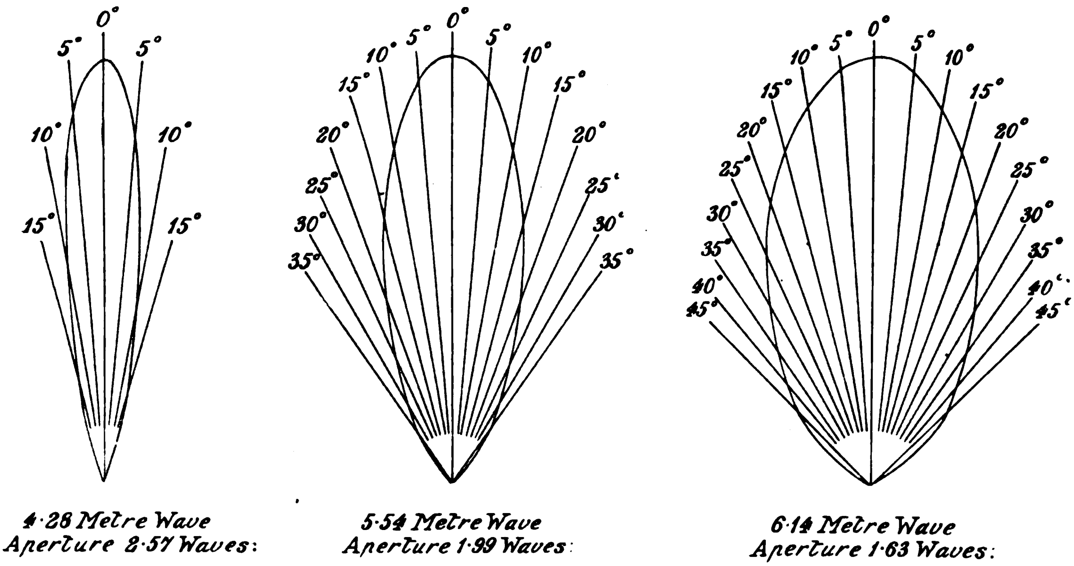


Fig. 8.—Polar Curves of the Inchkeith reflector, measured at a distance of 4 miles from the transmitter.

used at a distance no signals will be heard until the beam flashes past the receiver in the course of its rotation. The first practical step in this direction has been the erection of such a beam transmitter at Inchkeith Island in the Firth of Forth, while a second is in course of erection at the South Foreland.* At Inchkeith the rod oscillator emits a wave of about 6 metres length, this being concentrated into a beam by a wire parabolic reflector. The whole system makes a complete revolution about once in two minutes. As the beam rotates distinctive Morse signals are sent out as shown in the compass diagram in Fig. 9. To each second point of the compass is allocated a special letter, and the intervening points and half-points are marked as T and I respectively. As the beam flashes past the receiver the signal strength rapidly increases to a maximum and then diminishes, and if the succession of Morse signals received during this time is read the direction of the transmitter can be obtained by reference to the diagram. The direction is that of maximum signal strength or midway between the commencement and cessation of the signal heard. For example, when listening at the receiver the succession of signals IKITI would indicate a direction of half a point east of N.E. Confirmation of the signal can be obtained on another rotation of the beam at an interval of two minutes. The receiver on the ship consists merely of a half-wave rod, erected at the end of the bridge and connected up with a detector and valve amplifier to telephones or a loud speaker. With the receiver is provided a disc, marked as in Fig. 9, into which pegs may be inserted at the points corresponding to the commencement and end of the signal, and the bearing of the transmitter is thus obtained as midway between the pegs to an accuracy of a quarter point or about 2·8 degrees. When two or more beam transmitters are put into use the same characteristic signals may be retained for the two-point positions, but the intervening points may be characterised by some letter other than T as at Inchkeith, so that the train of signals ITI or, say, ISI will identify the transmitters, the letter I indicating half-points as before.

It will be appreciated that this system is fairly straightforward in use, and with a slight knowledge of the Morse code any non-wireless officer can operate it from the receiver-end. The method is independent of the time of revolution of the beam and so accurate timing and the use of a stop-

* J. A. Slee, "Recent Developments in the Application of Wireless Telegraphy to Shipping," *Engineering*, 1923, Vol. 116, p. 410.

watch are obviated. The working range of Inchkeith transmitter is about 10 miles, and as this is in daily use it will be interesting to watch for the results obtained from the point of view of its utility to navigation. Judging by experience in the propagation of wireless waves on wave-lengths of from 300 metres upwards, it is probable that the system will be entirely independent of prevailing weather conditions, and it should, therefore, be particularly useful in foggy weather when other lighthouses are invisible. In propagation over sea it is also to be expected that no other serious errors will be encountered, but when land intervenes the possibility of very serious errors due to reflection from cliffs and hills or refraction in crossing the boundary between land and sea is by no means remote. In fact, it has been suggested that the location of the reflected beam arising from a short-wave transmitter might provide a useful means of locating a near-by ship or even icebergs in the dark or thick fog.

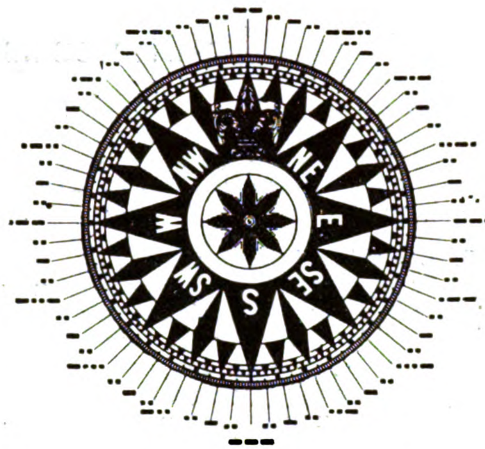


Fig. 9.—Compass bearings with letter designations for direction finding.

The Sheffield Relay Station.

The Sheffield relay station was officially opened in the middle of November, and, no doubt, some details will be of interest to many readers. The circuits employed are exceedingly simple and straightforward. A perfectly normal choke control system of modulations is employed, the schematic diagram of which is shown in Fig. 1.

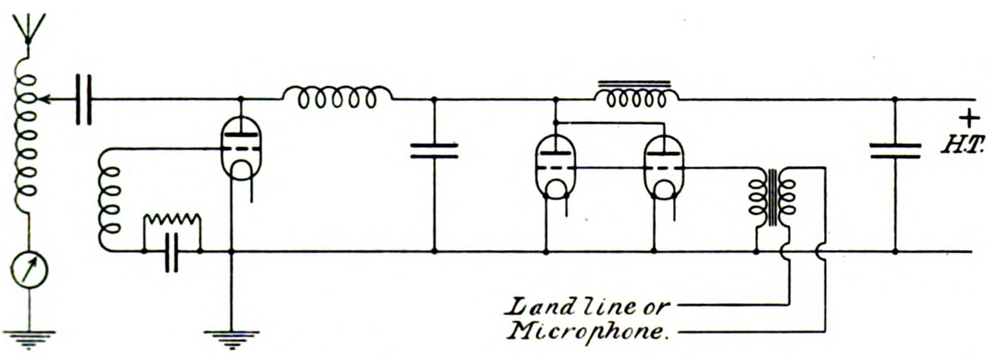


Fig. 1—Illustrating the fundamental circuit of the Sheffield Relay Station.

The present aerial consists of a four-wire cage about 120 feet high at the distant end; the earth screen consists of the iron framework of the building over which it is suspended. The set is rated at 100 watts.

Simultaneous Broadcasting.

By ALEXANDER J. GAYES.

Much interest is now centred round the subject of simultaneous broadcasting, and in order that our readers may be familiar with the methods employed we outline below the general mode of operation.

THE wireless broadcasting of a speech or a musical item simultaneously from several transmitting stations in different cities, as now so satisfactorily accomplished, has been rendered possible largely by the great advance made in recent years in the study of attenuation characteristics as applied to land line telephonic communication. The problems which present themselves on any such undertaking are many and varied, and, further, the necessity, for commercial reasons, of employing existing lines and cables often make the solutions unduly complex. Without taking a specific

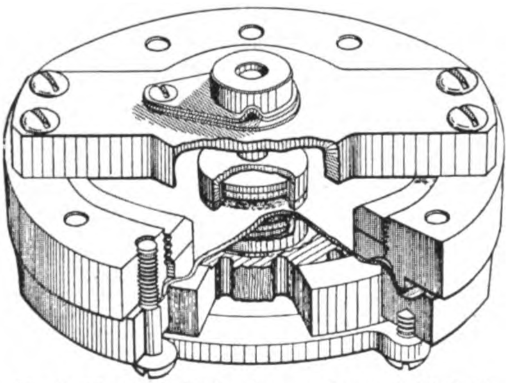


Fig. 1.—The push-pull microphone employs a stretched silk diaphragm, which is heavily air damped. The general form of construction should be apparent.

case, however, it is interesting to review the subject in the light of the most modern developments in the telephone art, in which respect credit must be given to the Western Electric Co. for the development of both the principle and the apparatus described in this article.

The two most important factors which enter into every problem of telephonic transmission are the attenuation and the distortion of the comparatively high-frequency waves which constitutes telephonic voice currents. By attenuation is meant the loss of energy of the waves of the telephonic currents, and distortion is the impairment of the many component waves of which the voice currents are composed. In a telephonic circuit the waves are slowly altered, both in form and in amplitude, as they progress along the lines, usually due to the wire-to-wire capacity, but by the addition of suitable inductance to the circuit this alteration can be very considerably reduced. The inductance is added at calculated intervals along the line in the form known as loading coils, and by means of these coils the original wave form and the initial wave amplitude can be preserved to such an extent as to bring the transmission efficiency of a cable under certain conditions up to six times that of an unloaded cable. More recently thermionic valves have been introduced in trunk line telephone circuits, and, owing to the amplification thus possible, the standard land-line speech transmission has now reached a very high level.

The requirement of the commercial telephone service, however, is intelligibility, whereas the transmission of high-grade music demands a naturalness which imposes far more severe electrical requirements, not only on the lines and cables, but on all associated apparatus. This is best expressed by saying that, whilst excellent speech transmission can be obtained with circuits and apparatus which function without material distortion between the frequency range of 400 to 2,000 periods per second, freedom from distortion over a frequency band of from 16 periods to 5,000 periods per second, or even higher, is necessary with music if each instrument in a first-class orchestra is to be discernible.

Obviously the first piece of apparatus to be considered in an extensive transmission scheme is the microphone. It is essential this be of a type which will faithfully convert every feature of the original sound waves into electrical energy; that is, it must function uniformly between 16 and 5,000 periods.

An air-damped stretched diaphragm condenser microphone gives excellent results, and these are being constructed with a thin steel diaphragm about 2 ins. in diameter, stretched until its period of vibration approaches 8,000 periods per second. The diaphragm forms one plate of a condenser, the other being a rigid disc, the dielectric consisting of a film of air approximately 1-1,000th inch in thickness. The high natural frequency of the diaphragm, coupled with the damping effect of the film of air, results in a very high quality of reproduction uniform in intensity throughout the musical range. The condenser microphone, although highly responsive, is extremely insensitive, needing a voltage amplification of 50,000 times (corresponding to an energy amplification of $2{\cdot}5 \times 10^{9}$) to bring its output up to that of an ordinary microphone, and, further, considerable technical knowledge is necessary in adapting this microphone to the input circuit.

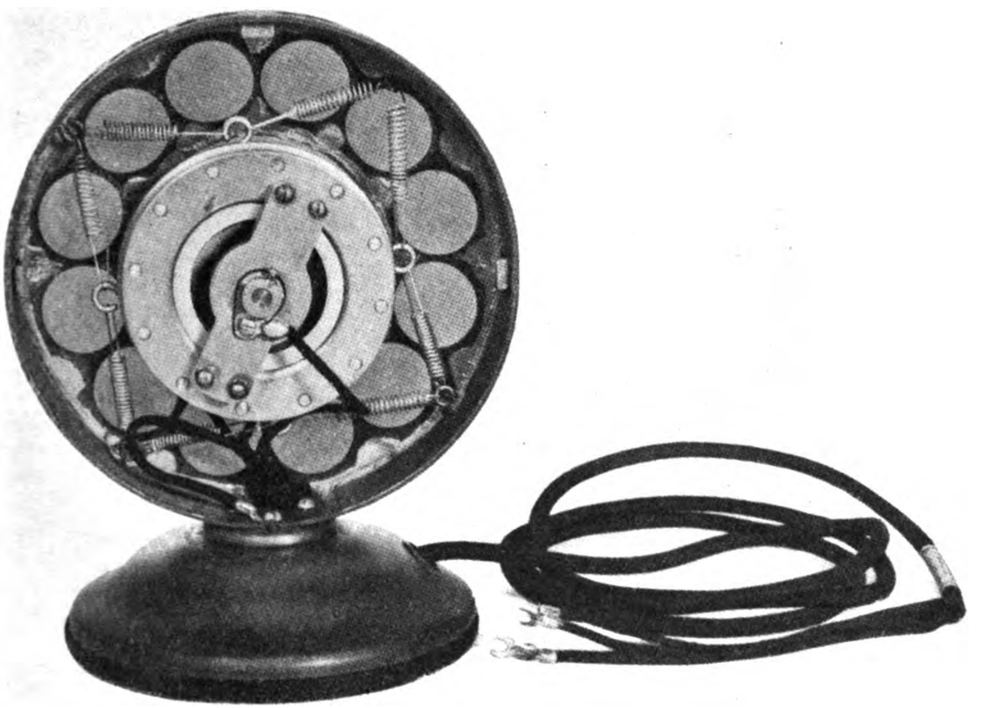


Fig. 2.—The push-pull microphone is normally suspended in a metal case by a system of springs so arranged as to reduce the effect of mechanical vibration.

A more manageable microphone, and one now in extensive use for high quality transmission, is the granular carbon type instrument with two buttons, one on each side of a diaphragm. This is commonly known as the push-and-pull microphone, and has nearly the same high quality characteristics as the condenser microphone owing to the use of a tightly-stretched diaphragm and the same principle of heavy air damping. The energy output of this microphone is, roughly, one-millionth part of that usual with ordinary microphones, and can be expressed as $1 \times 10^{+8}$ watt under average conditions. A part section view of the push-and-pull microphone is shown in Fig. 1, whilst Fig. 2 is a view of the microphone in its mounting with one side of the latter removed. It will be seen that the microphone proper is suspended on four hooks, which engage with spiral springs on the mounting in such a manner as to eliminate the effects of small mechanical jars and

vibration. An outer drum, having perforations on all sides protected by fine brass gauze, serves to form a cover, and it will be noted that no horn or sound collecting mechanism whatever is used with this microphone. In passing, it might be mentioned that the double button construction referred to above almost completely eliminates the distortion caused by the non-linear nature of the pressure resistance characteristics of granular carbon.

After leaving the microphone, and before the speech energy is sent out on the line, it is amplified, and if, for example, it were special three-valve amplifier illustrated. The microphone control apparatus consists of switches and other mechanism which enables the operator to switch quickly from one microphone to another, as with some public functions the speeches are made at different points during the ceremonies. Special precautions are taken to prevent clicks when switching from one microphone to another, and, if necessary, provision is made for two or more microphones being connected to the amplifier at one time. This latter feature is desirable when solo singers are accompanied by an orchestra in a theatre, for

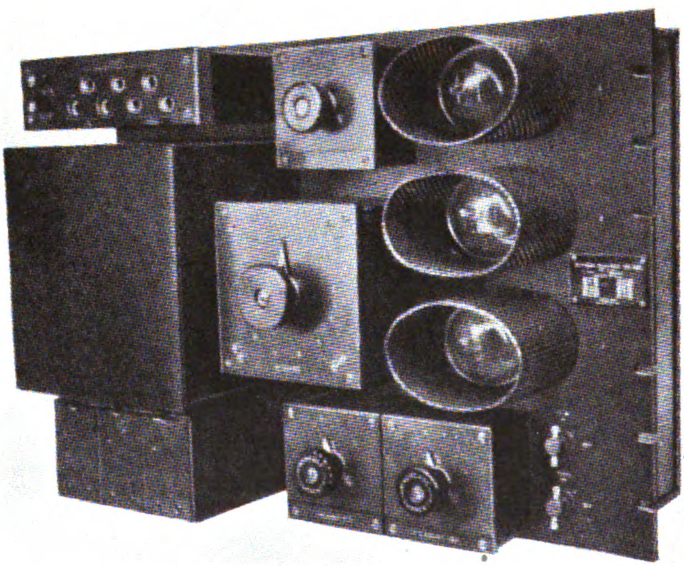


Fig. 3.—A general view of a speech amplifier panel with central devices. The screening of the valve is clearly seen.

desired to broadcast a theatrical performance, a very suitable apparatus would be the speech input amplifier, an illustration of which is shown in Fig. 3. The exact design of the amplifier would depend on conditions, but the aim is to produce an energy output approximating in value that of ordinary line telephones.

The circuit diagram of a speech input amplifier, suitable for microphones when the latter are arranged to collect sounds within a radius of several feet, is given in Fig. 4. For close talking a less powerful amplifier would suffice, but it is interesting to follow for a moment the operation of the example, where by proper adjustment of the respective volumes very pleasing results can be obtained.

It will be seen that the feeble currents from the microphone enter the amplifier through a differential input transformer on to the first valve. This valve is similar to the one following it, and by a clever series connection the filaments of both are fed from a common 12-volt supply. Advantage of this method of connection is taken to secure the necessary negative bias on the grid of each valve with the exception of the third valve, where a special grid battery is provided for the purpose. The third valve

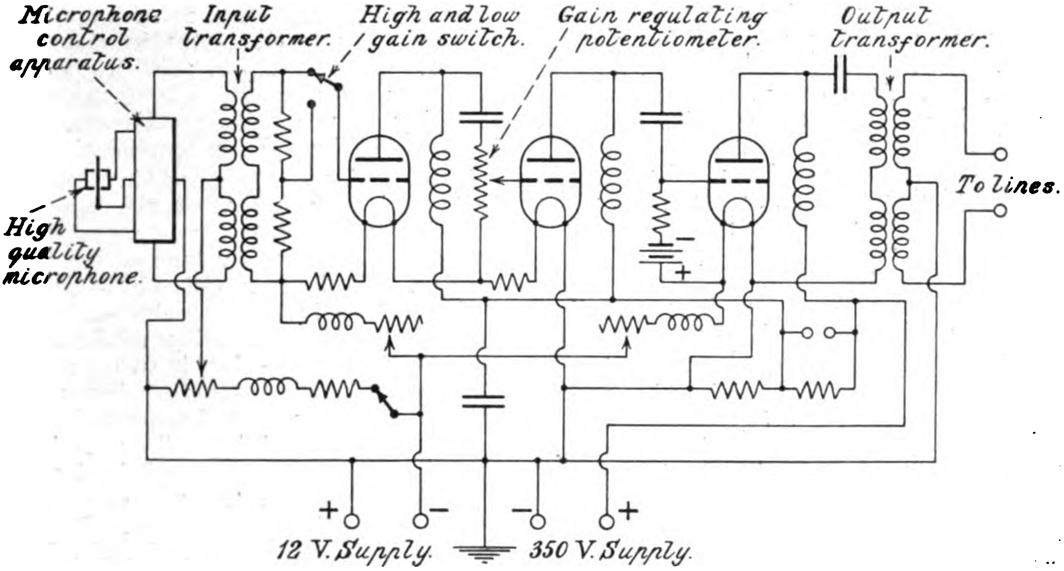


Fig. 4.—The microphone currents are applied through a differential input transformer to the first valve, the grid bias of which is determined by a series resistance. The subsequent valves are choke coupled, the grids being controlled by special potentiometric devices.

is of a different type to the other two, and current for filament heating is drawn direct from the 12-volt supply in this case. Needless to say the valves are of the latest oxide-coated dull emitter filament pattern, as with no other type would it be possible to secure so great a degree of amplification with entire absence of noise. From the last valve the output is taken to a special transformer, or repeating coil, as the telephone engineer would prefer to call it, out to the line through a winding, the centre point of which is earthed. This relieves the line of any static change, and generally makes it far less susceptible to interference effects by the employment of windings accurately balanced with regard to inductance, self capacity and speech-frequency resistance. From this point onward the transmission becomes a telephone problem of the highest class, and every effort must be made to maintain the value or power of the voice currents at a certain desirable level throughout the scheme. If the power be allowed to become too weak, the extraneous power induced from paralleling circuits would tend to obliterate the transmission. On the other hand, excessive amplification would overload any iron-cored inductances in the transmission line, and thus alter their characteristics, as well as giving rise to overhearing troubles on neighbouring circuits.

Referring now to the telephone transmission lines, as previously stated, these have been designed to function most efficiently between a frequency range of 400 to 2,000 periods per second. In other words, the attenuation at frequencies beyond this range is an uncertain factor, and thus we have the peculiar case of the modern telephone cable fitted with loading coils or repeater stations being inferior to an ordinary open wire for the transmission of the highest grade of music; that is, from a distortion point of view only, of course.

To understand the subject fully it is necessary to have a clear conception of attenuation and distortion as applied to telephone cables. These two effects are inter-linked, and the latter results from the former, but it is possible to eliminate distortion if only sufficient skill is exercised. This point can be made clearer if consideration be given for a moment to the study of the transmission characteristics of a telephone cable. Referring to Fig. 5, line A shows the transmission equivalent of a 10-mile length of ordinary dry-core paper-insulated cable. It will be seen that at about 800 p.p.s. the equivalent of the length is roughly 10 miles.

In other words, the cable under consideration approximates closely the accepted standard cable, on the basis of which all comparisons are made. At 2,500 p.p.s., however, the same length of cable exhibits properties similar to those of a 20-mile length of standard cable, assuming the latter to be functioning at 800 p.p.s. throughout, whilst at 5,000 p.p.s. the same 10-mile length of cable gives the effect of a 30-mile length at a uniform 800 p.p.s. From this it will be obvious that the attenuation taking place in a given length of cable varies according to the frequency of the impressed waves. In the case under consideration the loss at 2,500 p.p.s. is twice as great as it is at 800 p.p.s. In such a cable, with the energy loss varying with the frequency, the speech

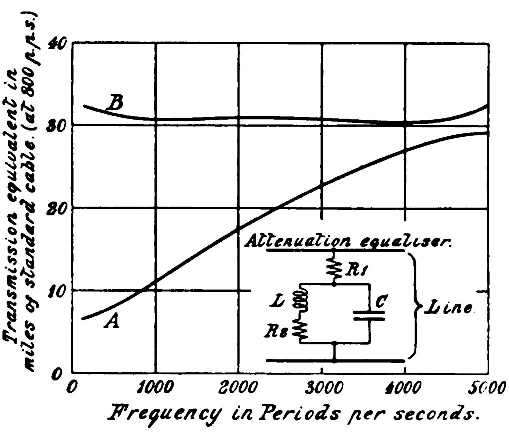


Fig. 5.—Illustrating the transmission equivalent without equalisers at A, and with equalisers at B.

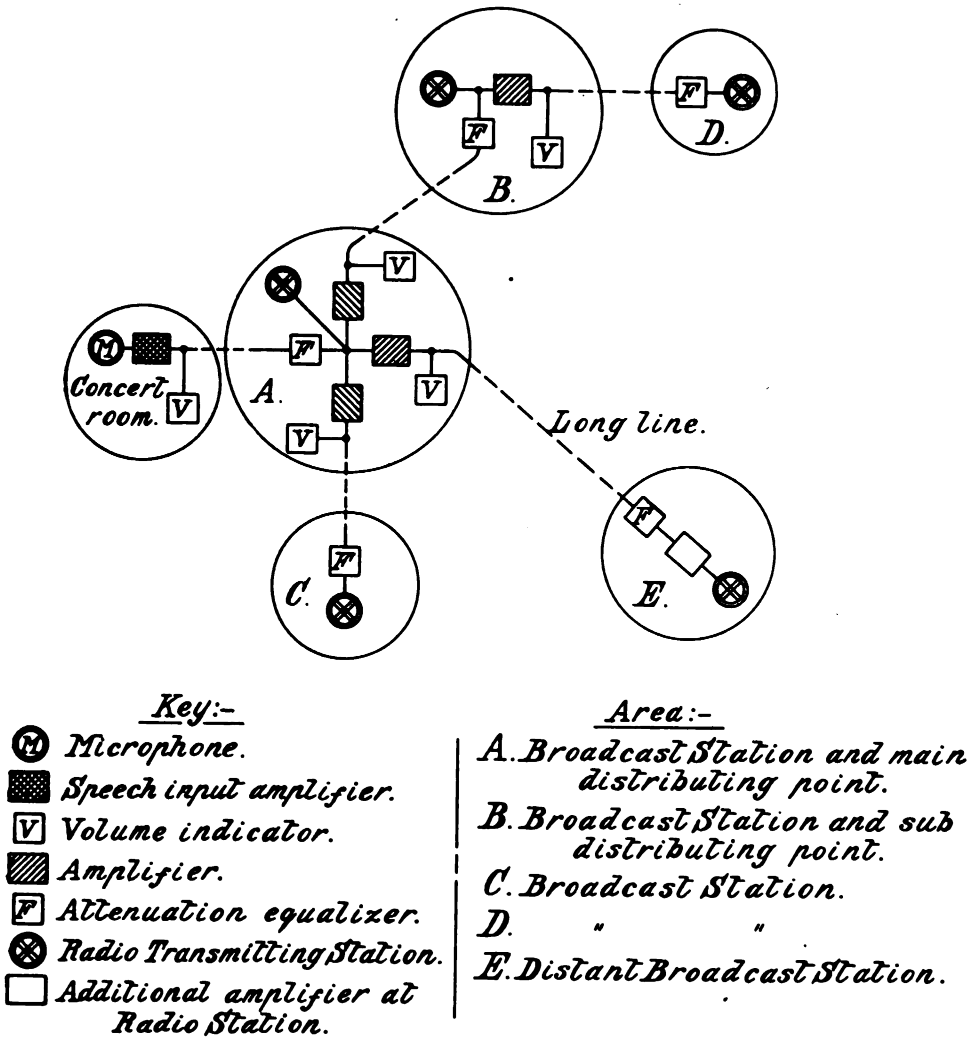
currents would suffer distortion, the degree of which would increase rapidly with widening frequency ranges.

By the addition of loading coils the attenuation, taken as a whole, can be reduced, and can be made more uniform throughout the speech range, but here the previously-mentioned wide range of from 16 to 5,000 p.p.s. must be considered. To secure uniformity throughout such a range is no mean feat, but it can be accomplished by the introduction of attenuation equalisers. Such an equaliser, as shown in the diagram (Fig. 5), consists of a calculated combination and arrangement of inductance, resistance and capacity. In a general way it could be said that such an equaliser increases the loss at the lower frequencies and results in a levelling up of the losses to such an extent as practically to eliminate distortion altogether. Curve B shows this clearly, and, although the nett result is a fall in the overall efficiency of transmission, this can easily be corrected by suitable amplification.

To maintain the desired level in the circuits by proper adjustment of the amplifiers it is found necessary to have some means for quickly indicating the volume of the transmission. This is accomplished by a " volume indicator " consisting of an amplifier detector operating a direct reading milliammeter. By adjusting the amplifier in such a manner as to keep the deflections of these instruments reasonably close to a point determined by previous calibration it is possible to maintain the volume or power of transmission between the required limits. In the case of an extensive distribution scheme small amplifiers can be fitted on all limbs of bridged or teed lines, and by means of volume indicators at these points the requisite amount of power or volume can be distributed to each station.

The volume indicators can be used in addition to compensate partially the large range in volume which occurs with music transmission ; this wide range being particularly noticeable if a theatrical performance is being broadcast. Consideration of this point will show that, were the amplifiers permanently set with sufficient volume to bring fully into prominence the words of a distant speaker, the volume of the loud music would be such as to overload the apparatus in the land lines, as well as the wireless transmitting and receiving apparatus, whereas by judicious use of the controls, based on the reading of the volume indicator, a more natural and pleasing effect can be secured.

The diagram will indicate the arrangement of apparatus involved in a typical simultaneous broadcast scheme. The speech input amplifier would be located in the concert room or in an adjacent room in the same building. A volume indicator would be provided, and, during a performance, an operator, who might also be provided with means of listening on a monitoring circuit, would regulate the amplifier to give approximately the predetermined output volume. This operator would also control the microphones if more than one were fitted.



At the main distributing centre (marked A) the incoming speech currents would be sent direct to the radio-transmitting apparatus, and also several amplifiers, as shown, would have their input circuits bridged on to the incoming lines. This is a fixed and steady load, which would remain unaltered by the demands of the several stations, these demands being met by amplifiers controlled by volume indicators as shown. The attenuation equaliser E in area A might prove unnecessary, as usually the concert room would be within a short distance of the main distributing point, but it is included to show the principle.

In actual practice many difficulties are encountered in attempting simultaneous transmission which cannot be detailed here; for example, the linking of cables to open lines, or the coupling of cables having different attenuation characteristics. If perfection is desired throughout the very wide frequency range of from 16 to 5,000 p.p.'s all such matters become difficult problems, and the satisfactory accomplishment of an extensive scheme of simultaneous broadcasting undoubtedly reflects great credit on all concerned with so complex a venture.

Some Experiments on the Fading of Signals.

By J. ALLAN CASH (2GW).

In the October issue of "Experimental Wireless" some information was given relating to some of the probable causes of the fading of signals. Below will be found some data which has recently been collected, and the results should be of considerable interest.

VERY little is known about the fading of signals, and investigation of this phenomenon is likely to lead to the solution of many problems in radio. The writer does not propose to put forth any new theories in this article, but rather to indicate the lines on which other experimenters may pursue their investigations, and to give some idea of his own experiences.

It is surprising how wide a field of investigation is opened up when one attempts to find out something about this interesting subject. Many theories have been propounded to explain why signals on short wave-lengths should vary in strength, but none of them can be said to be really satisfactory. When the atomic theory of matter was first propounded it became evident, as time went on, that many problems in science could be solved by it. The more it was used, the more evident it became that it was more than a mere guess, until to-day it is universally adopted as the true conception of matter, and has been proved beyond doubt to be correct. What is wanted in fading is a similar theory, which, once propounded, would probably solve many more problems than fading alone.

Fading only occurs in any marked degree between 150 metres and 600 metres. Below 150 metres and above 600 metres signals remain steady during a transmission period, although they may vary in strength from day to day. There is really no way of overcoming fading at the moment. It is no fault of either the receiver or the transmitter, but there is something between the two which has a very big influence on the signals. As is generally the case in electricity, there is no visible indication of the cause, so one is compelled to start guessing and to see how the information already in one's possession fits in with the suppositions.

Last winter the writer burnt the midnight oil with Mr. W. R. Burne and others many times. After the first excitement of hearing American amateurs had died down, certain peculiar features about these and other signals began to impress themselves on the listeners' minds. Fading was hardly ever spoken of then, but it soon became evident that signals from any American station were very difficult to copy in their entirety owing to the fact that they varied in strength so persistently.

At first regarded as a nuisance, this phenomenon soon began to interest the writer and his friends, and, while one read the messages, another would time the fading. Then things began to hum. It soon became evident that there were two distinct kinds of fading—one irregular and the other regular. This seemed something new, and enthusiasm ran high. Many signals were carefully timed, and soon another point made itself known.

Signals coming mostly over land faded very erratically—sometimes slowly, sometimes quickly, and at times remaining steady for various periods of time. There seemed to be no system about this, so attention was turned to signals which faded regularly. These were found in all cases to have travelled over large stretches of water, *e.g.*, Malin Head, Valencia Island, and American amateurs. These stations hardly ever faded irregularly.

The first thing to be noticed about this regular fading was that the time for a complete swing (*i.e.*, from maximum to minimum and back to maximum) varied with different stations. Next it was discovered that the time for a complete swing was directly proportional to the distance between the transmitting and receiving stations. From observations made last winter, and partly corroborated this autumn, it seems that one swing takes two and a half seconds per hundred miles. This, of course, requires further proof, and is at the moment only a

guess from comparatively few observations (see Fig. 1).

Malin Head was noticed to fade and return to normal strength in about six and a half seconds, being 250 miles away. Valencia took about 9 seconds, being 350 miles distant. A ship off Anglesey, 100 miles away, took 2½ seconds to fade. Other ships (C.W. harmonics on about 200 metres) all swung at the rate of 2½ seconds per hundred miles. It was, of course, necessary to find their exact positions, but once this had been done these signals formed excellent subjects for investigation. American amateur station 2ZL, belonging to Mr. J. O. Smith, of Long Island, New York, with which station special tests were carried out by Mr. Burne and the writer, took 80 seconds to fade and return. This station is 3,200 miles away, so the same thing applies in this case as in the others. Stations in the 5th and 9th Districts of America, *i.e.*, 4,000–5,000 miles away, took 100–125 seconds to swing. Further, whenever the fading of these signals was timed it was always the same.

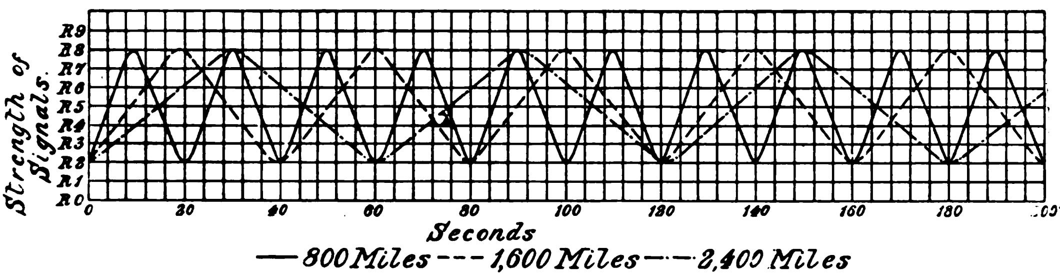


Fig. 1.—Fading curves of signals from 800, 1,600, and 2,400 miles.

A curious modification of this regular swinging was soon noticed (Fig. 2). After so many regular swings, a signal, beginning to fade as before, would be suddenly checked and begin to increase in strength again. This increase would be continued until the signal was far above its usual maximum strength. Then it would fade off again to its usual minimum value. After a few more regular swings, this process would be repeated only in the opposite direction, *i.e.*, fading away to far below minimum after increasing only about half way towards normal maximum strength.

An excellent demonstration of this modification was given on January 17, 1923, between 2 and 3 a.m., by station U.S. 2ZL. His strength at full maximum made it impossible to wear the 'phones. When at full minimum his signals were just readable. His normal swing varied between R.5 and R.9 or more.

It is very difficult to observe this modification of fading, as a station would have to transmit consistently for at least a quarter of an hour in order to demonstrate all the fading without doubt. This is very rarely done by American amateurs. Perhaps it would be easier to watch broadcasting. There are many things to be discovered yet about this strange double fading.

Perhaps it would be as well to mention here that fading varies from night to night. Last winter the fading of American amateurs seemed consistently to follow the above conditions, but since the summer their fading seems to have been influenced by some unknown cause. Very often quite irregular fading has taken place, and on many occasions the time for a complete swing has been wrong. However, bearing in mind last winter's results, it is quite easy to see that the fading tends to follow the same rules.

Now a word to those who have noticed regular swinging on English broadcasting stations. Several experimenters have written to various wireless periodicals saying that signals from London at a few hundred miles distant fade regularly every so many minutes. Quite right, but does London always fade in the same time? If so, by all means take as many observations as possible and try to find the cause of it. But if, when swinging regularly, the time for a complete swing varies from day to day, it seems to the writer that it would be far better to watch stations which always or nearly always fade regularly,

find out something definite about regular fading, and then compare the results with the occasional regular swinging of London. In this way it should be much easier to detect the influences which cause irregularities in the fading of signals coming over land. By watching stations which only occasionally swing regularly one is apt to get lost in a maze of observations, in which irregular swinging predominates.

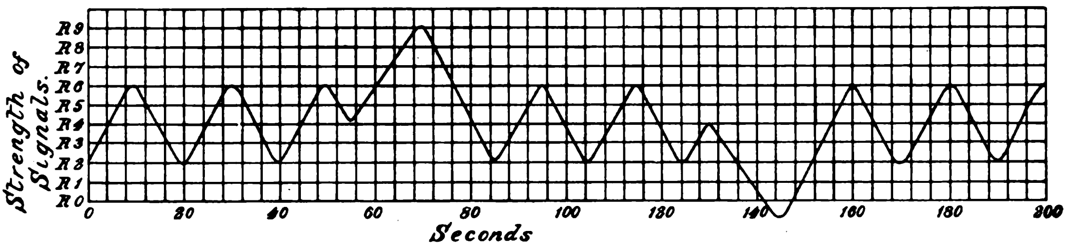


Fig. 2.—Fading curve of signals from 800 miles, showing double increase and double fade.

To those who have observed fading on European stations, and compared it with that of American stations, there are so many things which seem to influence signals coming over land that for convenience sake, for the time being anyway, it seems better to class all "local" stations as fading irregularly, and to concentrate on the best of all stations to observe on—American amateurs and broadcasting. As signals on 400 metres seem to fade in exactly the same way as those on 200 metres, American broadcasting is very useful to those who require a good "steady" signal to work on.

A most important point to remember when observing fading on a telephony transmission is—not to take the strength of the signal as being that of the music or speech, but to heterodyne the carrier wave and observe on that. Music is always varying in strength regardless of radio conditions. Speech, if consistent, is less likely to lead to mistakes, but better than either of these is the carrier wave. Great care must be taken if a self-heterodyne type of receiver is used to see that the set does not radiate, as this would probably spoil reception for others in the vicinity. It is far safer to use a separate heterodyne altogether, coupled, if necessary, as far from the aerial as possible. If a self-heterodyne receiver is used, it is easy to determine whether radiation is taking place or not by tuning in a C.W. signal and then moving the aerial tuning condenser, or, if a coupled circuit is used, the secondary tuning condenser. If the set is radiating the beat-note of the signal will change, but if no radiation is taking place only the strength of the signal will change, the beat-note remaining the same.

The writer's present receiver consists of six valves—4 H.F., D., and 1 L.F. Any number of valves can be used at a time. The H.F. valves are transformer coupled. When the H.F. valve nearest the detector is used alone, the set radiates when oscillating, but when any more H.F. valves are brought into action they do not oscillate along with the first one. The heterodyning part of the set remains confined between the detector and the first H.F. valve, and with two, three or four H.F. valves in action the set does not radiate. This enviable state of affairs is only made possible by using reversible H.F. transformers—*i.e.*, with the four pins fixed in the form of a square and not in the usual valve-pin way. It often happens, when the writer brings another H.F. valve into play, that the whole set oscillates, and therefore radiates, but by pulling out the last transformer to be added, giving it a quarter turn, and again inserting it, the general oscillation ceases and there is no radiation. Signals are every bit as good as when the set radiates. The condenser tuning the transformer nearest to the detector is the only thing which will alter the beat-note of a signal when the set is adjusted correctly. By using reversible H.F. transformers, self-oscillation between H.F. coupled valves has been entirely eliminated at 2GW.

It will be seen that the writer pins great

faith on H.F. valves. Perhaps some readers will question the necessity for so many valves. Let it be stated at once that signals from America can be heard quite easily on one, two and three valves, but in order to obtain accurate data on fading it is highly advisable to more than merely hear a signal. A signal should not fade to inaudibility at all, and, if possible, should be easily readable when at its weakest. It has been found that, when QRN is bad, the L.F. valve is more trouble than assistance in reception, but by bringing in one or two more H.F. valves, QRN is but little worse, while signals are considerably louder. It is very rarely necessary to use all the H.F. valves, but they are there for use when the occasion arises.

The writer has not troubled very much with record-breaking achievements, although American signals on short waves have been read on one valve, and various other "stunts" have been achieved "just to show there is no ill feeling!" Much more importance is attached to the scientific side of reception than to record breaking. After all, what one fool can do, another can!

During last year's Transatlantic Tests signals came through very well until December 15, when they began to go off. On December 16 only two American amateurs were reported among all listeners in Great Britain. December 17 saw signals returning, and December 18 was a very good night. Here is a chance for investigation. Signals from America often go off like this, but generally return after a day or two. Local signals remain apparently the same as usual during these periods.

During September of this year great numbers of American amateur and broadcasting stations were received in England, but for the first four weeks of October no one, to the writer's knowledge, has heard more than a solitary one or two American signals. Why? Is it weather conditions, wind, temperature, clouds, humidity, or what? Further, is the cause of signals going off during last year's Transatlantic Tests the same thing that prevented signals coming across during October this year? These and many more questions remain to be answered. The only way to do it is to imagine everything that could possibly influence signals, obtain regular information about each thing, draw graphs if possible (Fig. 3), and compare them with the results obtained. Perhaps in this way some experimenter will come across a feature of Nature which influences signals, and which would account for fading of all kinds. Anyway, there is a vast field of research open to all who are interested, and no unusual or costly apparatus is necessary to begin with at least. Perhaps other experimenters will make known their views on this most fascinating subject.

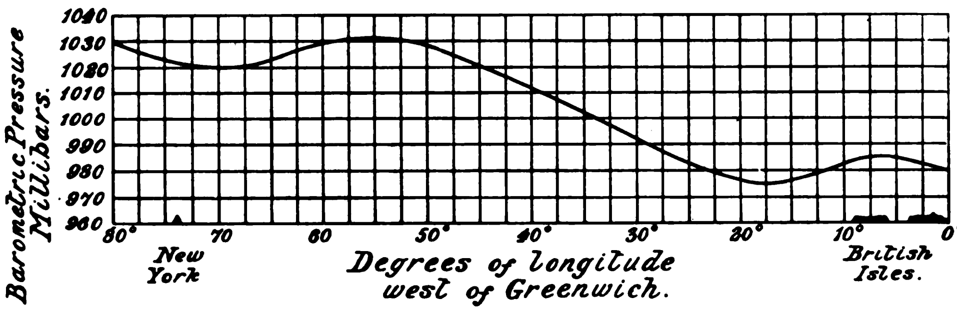


Fig. 3.—Chart showing barometric pressure over the Atlantic Ocean on December 20, 1922. It was found that very good conditions for reception existed at this time.

British Amateur Call Signs.

It is understood that the supply of call signs commencing with the figure 6 is now exhausted. It seems that other figures are not to be introduced, and the call signs will be continued by another series of "twos," followed by various three-letter combinations. It needs little imagination to appreciate the confusion which is likely to arise when listening for American amateurs.

Some Original Notes on Selectivity.

By G. L. MORROW (6UV).

Since the introduction of broadcasting the experimenter has turned his attention to the question of selectivity with a view to separating the various broadcasting stations. Most time seems to have been devoted to the use of rejector or acceptor circuits, and the following notes which approach the subject from a different view-point are of great interest.

IN the early part of the present year the writer was engaged upon the compilation of comparative data with respect to the fading of certain 600-metre marine traffic shore spark stations, and for the purpose of these investigations a receiver, comprising two aperiodic H.F. stages, rectifier and one note magnifier, was employed; the tuner being a standard, calibrated Mark III*.

To those who are conversant with 600-metre reception, it will be appreciated that anything in the nature of accurate signal strength measurement on any given station is practically impossible on this wave-length owing to interference.

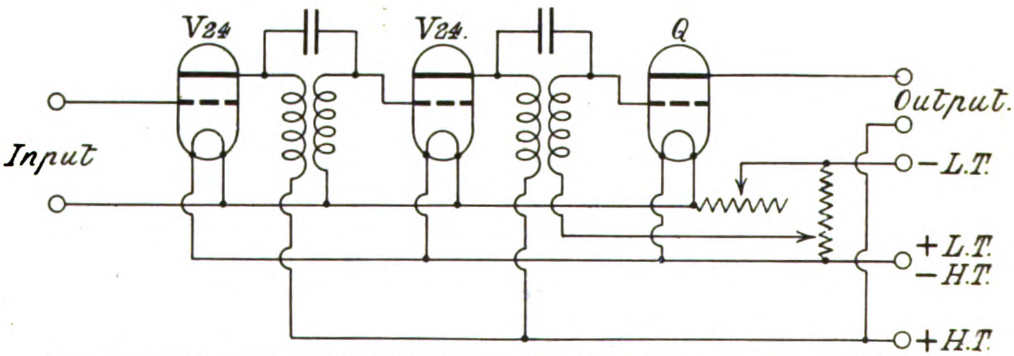


Fig. 1.—Small fixed condensers are placed between the primary and secondary of the transformers—that is, between the anode of one valve and the grid of the next valve.

It is hoped, therefore, that the methods to be described by which this interference was overcome may be of interest, opening out, as they do, an interesting field for research in amateur DX working in this country.

In considering the means by which this interference might be reduced, one of two methods only appeared to hold out reasonable chances of success, one being to strive for the utmost degree of selectivity obtainable by small a coupling percentage in the tuner as compatible with signal strength; the other, by the use of rejector circuits or what are commonly known as "wave traps." As it is well known that by far the greater amount of 600-metre spark interference is caused by the "double-wave" radiation of such stations, it was decided to concentrate on obtaining as high a degree of selectivity throughout the receiver as was possible, and it was proposed to use the minimum coupling between the aerial coil and the secondary, together with a high degree of resonance in the H.F. stages, according to the particular station whose fading was to be observed.

For some months previous to the commencement of these investigations it had been noticed that the weather report transmitted nightly from GLD at 22.30 G.M.T. was subject to marked periodic fading, and it was, therefore, decided to start observations on this station. Owing to jamming by FFU and GNI such observations were of little value, and the writer therefore tried the effect of putting small variable condensers of 0·00025 mfd. maximum capacity in shunt to the secondary windings of the transformers. It was found that a capacity

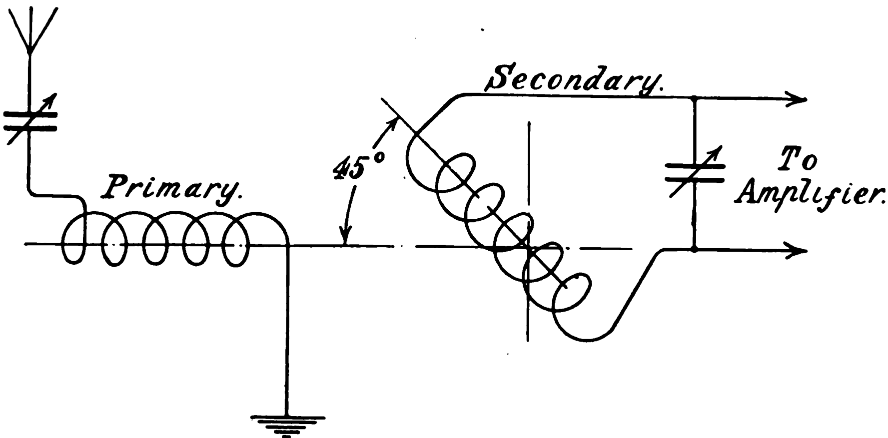


Fig. 2.—The longitudinal axes of the coils were first placed at 45°, as shown.

of 0·0003 mfd., together with the limiting action of the rectifying valve—anode rectification being employed—was sufficient to bring up GLD's strength from an average of R6 to R8 without increasing that of FFU or GNI. Two fixed condensers of this capacity were then made up with the intention of connecting them permanently across the transformer secondaries ; this was done, and a strange effect was immediately noticeable: whereas previously it had only required two divisions of the secondary (tuner) condenser to bring in FFU and GNI sufficient to jam GLD, it now required twelve divisions, and when tuned to GLD the two former stations were of very much reduced strength.

As no logical explanation of this effect was apparent, the wiring of the amplifier was examined, more by custom than in the hopes of finding an explanation, and it was then found that by mistake the small fixed condensers had been connected, *not* across the secondaries of the transformers, but *between* primary and secondary, as shown in Fig. 1. Thus the writer is bound to admit that what he might have striven for unsuccessfully for weeks was, through carelessness, discovered in a few hours.

At this stage it was decided to leave the amplifier as it was and employ the loosest coupling possible in the tuner, and it was discovered that, when the longitudinal axis of the secondary was at 45° with that of the primary, as shown in Fig. 2, GLD was quite inaudible, while FFU and GNI were reduced to strength R3 and R2 respectively. When, however, the coupling was still further reduced to approximately 85°, GLD became audible again at strength R4, FFU and GNI being both reduced to strength R2.

As these results were promising in the extreme, the primary and secondary coils were removed from a spare Mark III* tuner and mounted in such a manner that the secondary coil could be removed to a distance of 2 ft. from the primary, the longitudinal axis of both coils being the same, and, profiting from the experience of the H.F. transformers, a small variable condenser of 0·0005 maximum capacity connected as shown in Fig. 3.

At this point it may not be out of place to investigate the function of the condenser shown in Fig. 1. It should be remembered that the high-frequency transformers were of the aperiodic type wound with resistance wire, and thus, in their original condition, giving a comparatively speaking blunt, resonant peak on 600 metres. The effect of adding a small condenser in the position shown in the diagram is to increase the capacity between primary and secondary, thereby still further flattening out the resonance curve on the optimum wave-length. This, combined with the selectivity obtained by very loose-tuner coupling and the limiting properties of the rectifying valve, enabled the two interfering stations to be very much reduced in strength. In passing it may be of interest to mention that the true wave-length of GLD as measured by a

standard wave-meter was 605 metres, with only a weak radiation on 585 metres, whilst the true wave-length of FFU and GNI were noted as 595 and 620 respectively.

Reverting now to the special tuner, it was found that, with the secondary coil removed to 1½ times its own length, and connected as shown in Fig. 4, when the coupling that the shorter the wave-length with any given coupling, so the static component increases, and on wave-lengths below 300 metres the writer uses a vernier condenser of 0·0002 mfd. maximum capacity.

This method of what may, perhaps, be termed a combination of inductive and capacity coupling was sufficient to enable

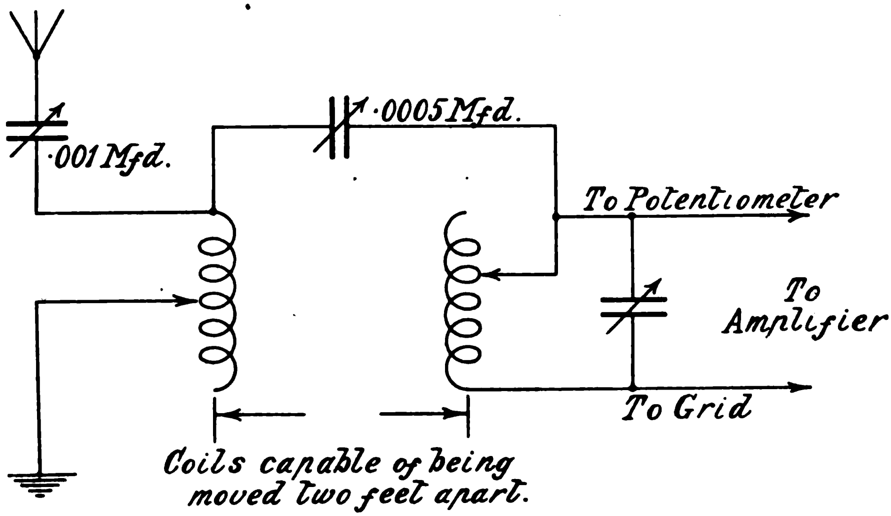


Fig. 3.—Subsequently the coils were separated by a distance of 2 feet, the axes being alligned, and the coils were electro-statically coupled.

had been loosened sufficiently to obtain the dead point on GLD a slight movement only of the condenser was required to bring this station in again at quite good strength, at the same time eliminating the two interfering stations.

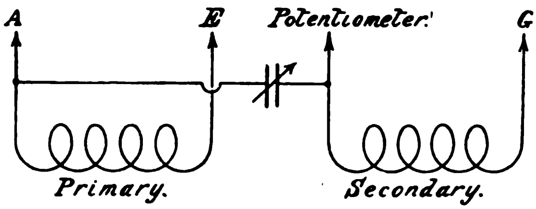


Fig. 4.—The secondary is removed from the primary to a distance of 1½ times its own length.

It would appear that, at the silent point, the coupling is so reduced that the magnetic and static components are equal, and that any further reduction in coupling results in the static component being the greater, thus giving in effect a capacity coupling which is actually accentuated by the small variable condenser. It would also appear the necessary data on fading to be tabulated, and the results obtained were considered to be sufficiently interesting to warrant similar observations being taken on several British amateur stations operating round 200 metres. On this much shorter wave-length it was found, however, that this method was not wholly satisfactory on C.W. transmissions, as certain stations continually broke through and rendered observations almost impossible.

This was finally overcome by replacing the aperiodic secondaries of the H.F. transformers with tuned copper windings, and at the same time arranging variable coupling between the primaries and secondaries of these transformers. This gave all the selectivity necessary, and the final circuit is that shown in Fig. 5.

This, at first sight, would appear to necessitate several critical adjustments, but in practice the writer has found that once the "feel" of the circuit has been obtained stations can be tuned in and interfering stations eliminated with comparative ease.

In any case, the remarkable degree of

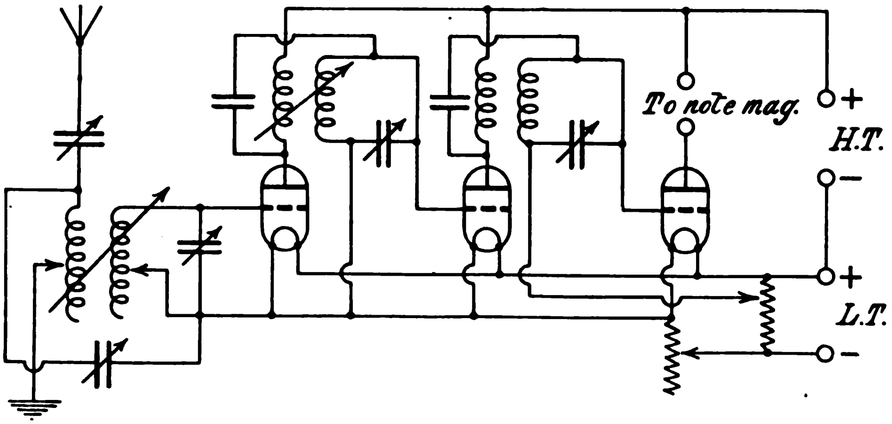


Fig. 5.—The final circuit employed, with the selective device applied both to the aerial circuits and the amplifier circuits.

selectivity which can be obtained by these means appears amply to justify the extra adjustments required. It will be noticed that throughout these notes no mention of reaction has been made. Reaction was tried, but, as would be expected, rendered the circuit unstable, and, since the signal strength was quite sufficient, and no tendency to instability apparent without its use, it was not adopted. Finally, as a matter of interest, using this arrangement, the 450-metre ship and shore D.F. traffic, which so frequently cuts through the broadcast transmissions from 5IT, can be completely eliminated, as also can the interference of any one broadcasting station with another at a position 30 miles N.W. of London.

In conclusion, the writer has made no attempt to deal with the theoretical explanation of the various phenomena observed, but has given these notes in the hope that they will prove of interest as showing in what manner a definite problem arose and how it proved capable of solution to such an extent that the observations on fading were able to be completed.

Copy of letter received from U.S.A. 8KG.

Niles, Ohio.

English 2KF. October 21, 1923.

DEAR SIR,

We have completely verified your report of September 19 on our 'phone signals, and we wish to thank you for same.

The report has been officially recognised by *Q.S.T.*, the leading American amateur wireless magazine.

Perhaps you do not realise it, but you have helped us to establish a world's record. The 'phone set we were using at the time incorporated four 5-watt tubes in a Hartley circuit, using Heising method of modulation, two tubes acting as oscillators and two as modulators, the input being 500 volts D.C. at 180–200 milliamperes, or about 100 watts.

This set radiates from 2·3 to 2·5 amps. on 'phone, the voice being amplified by a special two-stage amplifier before it is impressed on to the modulator tubes.

As you will now realise, this is some record for low-power 'phone set such as this one is, and we should like to arrange tests with you at some time in the near future. . . . .

Again we wish to thank you for your very kind report.— Yours truly,

(Signed) J. WM. KIDD,

Oppr. 8KG.

Note.—This station was received when working telephony to 2RS on the morning of September 19, 1923, at 4.50 a.m., using two valves (detector and 1 L.F.), and the speech was just audible, the calls being easily recognised. The transmission was steady, and no fading was observed. 2KF.

General Efficiency of Reception on Short Waves.

By HUGH N. RYAN (5BV).

A recent examination of a number of amateur receiving stations intended to operate on short wave lengths shows in a very large number of cases very poor examples of design. In view of the coming trans-Atlantic tests it is likely that many will be working on very short wave-lengths and those to whom the subject presents any difficulty will find the following notes helpful.

IN reading reports of the reception results obtained by various stations, one cannot but notice the great differences exhibited in the logs of different stations, which differences are too great to be accounted for entirely by the location of the stations. It is very interesting to look through the "Calls Heard" columns of several radio periodicals. One can "place" each station in its right class immediately. First look at the end of the list. Either there will be a string of O's and 8's, or there will be none at all. In the latter case, you can be pretty sure that every station in the list will be a 440-metre station. In some cases there may be some very good work indicated on the 440 wave-length, in the way of distant stations received, this showing that the station in question is not entirely "dud," in spite of his evident inability to receive on 200 metres. The chief object of this article, therefore, is to give a few hints to those who are experiencing difficulty with the short waves. I can hear many of you saying that a man who cannot receive as well on 200 as on 440 does not deserve hints. I would ask those to consider the time when their own 200-metre reception was, perhaps, not all that might be desired. It is even possible that, in a few cases, there is still room for improvement. Certainly, in the aforementioned lists, the results on short waves, when there are any recorded, are not always comparable with the receivers used. So, you who get everything there is to get on short waves, why not try getting the same results on one valve less? (In a few cases I know of, I should like to suggest four or five valves less!)

First of all, we will deal very briefly with those who cannot receive at all below about 300 metres. Their troubles can be reduced to three main headings. Too much dead-end. Too large a reaction coil. Too much stray capacity.

The remedies for the first and third are obvious, and have been emphasised too often to need any further remarks. The fault of having too large a reaction coil is probably responsible for 90 per cent. of short-wave troubles. Those whose receivers work only on the longer waves find that, as they tune downwards beyond a certain point, they need more and more reaction to make the circuit oscillate. A little further down the circuit will not oscillate at all. Strong spark and telephony can still be received fairly well, but it is noticed that, however much further the A.T.I. is reduced, the wave-length does not decrease. Now the point below which the reaction coupling has steadily to be increased is the natural wave-length of the reaction coil (or, more correctly, of the circuit comprising the reaction coil and the valve capacity). No circuit will oscillate freely at a frequency higher than its own natural frequency. Therefore, the oscillations which are obtained a little below the point are forced and unstable, and cease altogether a little lower down. The reason that reducing the A.T.I. fails further to reduce the wave-length is that the reaction coil has now taken charge of the tuning. It must be remembered that, although when we say that a set is "oscillating," we usually mean that it is generating oscillations of itself, yet the circuits of a receiver are oscillating whenever it is receiving signals, the oscillations being sustained by the distant transmitting station instead of the receiver. So, for the same reason that the circuit cannot generate oscillations below the natural wave-length of its largest coil, it cannot respond to signals of a lower wave-length

than that. This explains why the reaction coil takes charge of the tuning as soon as the natural frequency of the grid circuit in the ordinary receiver is increased (*i.e.*, its natural wave-length reduced) above the natural frequency of the plate circuit.

Now, many experimenters do not realise this, and so, when they observe that, below a certain point, they require more reaction, and that a little lower still they cannot obtain oscillation at all, they assume that they have not sufficient reaction for short waves. They therefore put in a larger reaction coil, and so make matters worse.

Assuming that the coils are arranged so as to allow of a reasonable (but not necessarily tight) coupling, and that the damping of the grid circuit is not too great, a very small coil indeed will suffice for reaction. I have very often heard this excellent advice met with the reply that the set might be persuaded to oscillate a bit with a small reaction coil, but the oscillation would be pretty feeble. May I, therefore, interpolate at this point a few sentences dealing with popular ideas about oscillation. Oscillation is the fetish of the average non-technical experimenter. His first thought about any receiver is not " Will it receive ? " but " Will it oscillate ? "

The guiding rule of many receiving men is " if the set will oscillate it must be working, if it will oscillate hard it is working well, if it will howl violently it is working perfectly." Hence the often-heard objection to a small reaction coil, namely, that it will not make the set oscillate hard enough. Let us try to explode this fallacy once and for all. A good autodyne set of any ordinary type is working at its best for the reception of C.W. when it is just oscillating. Theoretically, the signals heard in the 'phones are loudest and purest when the local oscillations in the circuits of the detector valve are of exactly the same amplitude as those produced by the received signals. Now, with the slight degree of overlap present in the majority of receivers (even if it is too slight to be noticeable) the weakest stable oscillations which our receiver can generate are stronger than those which we are receiving. Therefore, always try to keep the receiver only just oscillating for C.W. reception, and on no account blame your receiver because it will not oscillate hard enough. Another very important point must be mentioned in this connection. Whatever the text-books may say about it, it is an indisputable fact that if a receiver is connected to an aerial, and any valve of that receiver is oscillating, some energy will be radiating from the aerial. The tuned anode H.F. amplifier, with reaction coupled to the anode coil, is no more free from this trouble than any other. If the set be tuned correctly, and the detector valve is generating oscillations, the H.F. valve will oscillate also and energise the aerial. So there is another important reason for keeping the local oscillations subdued. It has been said that the amplitude of the local oscillations should be equal to that of the received oscillations for the best results. In connection with this, it will be understood that the remarks about the local oscillations in an autodyne set always being in practice stronger than those received only apply when receiving weak signals, but, of course, the set does not need to be at its most sensitive adjustment for receiving a station in the next street.

If this ideal of equalising local and received oscillations is achieved, then the interference caused by the receiver is minimised. It means that, even if reaction direct on to the aerial coil were used, the interfering waves received by any other station, however near, could never be stronger than those of the distant station. Now, if all the usual precautions are adopted, and aerial reaction barred, the interference can be eliminated, and reception improved at the same time. In connection with the last two matters, one cannot too strongly urge the use of a separate heterodyne. It is the only method by which the strength of the local oscillations can be regulated to a nicety, and the most effective method of minimising the so-called re-radiation.

Now, having reduced the size of the reaction coil, it is possible that the set will still not oscillate on short waves. This may be because the reaction coil has not been sufficiently reduced. In this case the receiver will exhibit the same symptoms as before, but on a lower wave-length. But assuming that the reaction coil is now small enough, the trouble is probably due to an excessive dead-end, or too fine a gauge of wire on the A.T.I. or grid coil. For the best results on short waves, use a coil which just covers the required range and no more. From

150 to 220 metres is a reasonable range for one coil, with, say, three or four tappings. Use plug-in coils if you like them, but make them yourself, using thick wire for winding. The universal fault with all short-wave plug-in coils on the market is that the wire used is far too thin.

All coils for short-wave work should be wound at least 18 or 20 gauge wire. See that all the connections are made with heavy gauge wire, as short as possible, well spaced, and all joints soldered.

Use a well insulated counterpoise in preference to an earth connection wherever possible.

Now, having reduced all damping to a minimum, adjust the set to the highest wave-length on which it is required to work. It should just oscillate on this wave-length. If it oscillates readily with very little reaction coupling, take more turns off the reaction coil. After adjusting everything in the circuit to its best value, the reaction coil should be just large enough to produce oscillation over the whole range of wave-length.

I have already pointed out that it is essential for the natural wave-length of the reaction coil to be below that of the received signals, but so far it has been assumed that it does not matter how close to its natural wave-length we work so long as we keep above it. As a matter of fact, it is best to keep its natural wave-length as far as possible below that on which we wish to receive, for two reasons. The first is just a matter of mass, and has nothing to do with frequency. We do not want to introduce more matter, especially metal, into the field of the grid coil than is necessary, owing to eddy current losses, which may be quite high on these frequencies. The second reason has to do with smoothness in tuning the set. If the curve, obtained by plotting wave-length against the degree of reaction required to produce oscillation, is examined it will be found that it is fairly flat at a distance from the natural wave-length of the reaction coil, becoming steeper as it approaches that wave-length. In other words, if we want to keep the set just oscillating, while varying the wave-length, the necessary adjustment of the reaction coupling will be slight if we are working well above the natural wave-length of the reaction coil, but becomes greater as we approach that wave-length. This means that "searching" becomes very troublesome if we are working only just above this natural wave-length, since, if the set is just oscillating, raising the wave-length slightly brings the set "miles off oscillation" and lowering the wave slightly causes it to oscillate much too hard. Thus, for every reason, it is best to have the reaction coil as small as possible. The last reason applies with still more force when a separate heterodyne is used, as the receiver is then used "just off oscillation" instead of just oscillating, and, if these suggestions are followed, the set will be in this state over a small band of wave-lengths without adjustment of the reaction coupling, thus reducing the number of controls.

Finally, if this article helps anyone to improve his results on short waves, will he please remember that there are others trying to receive the same signals as he is, and that, by yielding to the temptation to let the set oscillate hard, he is spoiling other people's reception as well as his own. If people in the same neighbourhoods would co-operate in avoiding interference, things would go much better. I was listening in a few nights ago and heard about 40 American amateurs. The call signs and some of the traffic of 25 of these were completely blotted out by one local heterodyne.

If you must use autodyne receivers, use them carefully. Don't "swish" up and down anyhow, and remember that if one station in a neighbourhood is listening with a radiating aerial to a distant station, and he *keeps still*, all the others can keep just off oscillation point and receive fairly well, using the other man's radiation as a separate heterodyne, but one man "swishing" will ruin everything. So use a separate heterodyne if you possibly can, and whatever happens, if you hear anything, go for it carefully and steadily. Don't get wildly excited and "swish" up and down on the signal. A little friendly co-operation is worth a lot of fancy anti-radiation circuits.

American Broadcasting Stations.

It is interesting to note that at the time of going to press, the American broadcasting stations are now being received some 50 per cent. louder than during the last month.

Some Notes on the Sources of Energy Loss in Condensers.

By PHILIP R. COURSEY, B.Sc., F.Inst.P., A.M.I.E.E.

The occurrence of losses in condensers, and their resultant effect upon a particular circuit, is a subject of which the experimenter has had little chance of investigating. Below will be found the first part of a simple discussion, and should prove of considerable value to those to whom the subject is new.

WHEN, as in the early days of electrical work, the use of condensers was confined to the storage of small high-voltage electrical charges, absence of leakage was a property of prime importance. Condensers were then of the Leyden jar form with a glass dielectric, and probably their chief application was to Wimshurst and similar electrical machines.

The phenomena of dielectric absorption and residual charge gave then an indication that the properties of the dielectric in such condensers were more complex than was to be suspected from the straightforward charge

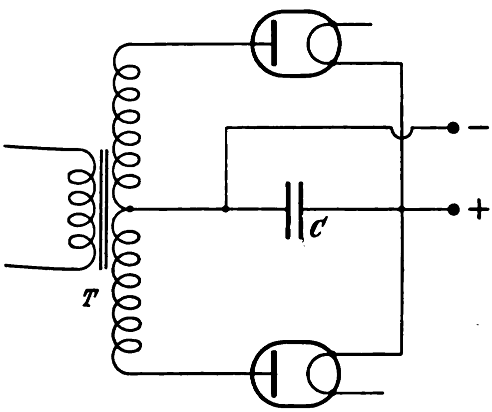


Fig. 1.—A typical arrangement of a smoothing condenser for double wave rectification.

and discharge effects, while this complexity has only been further emphasised by recent developments in high-power continuous-wave radio.

Considering for a moment this question of insulation resistance, it is evident that when a condenser is maintained charged by a source of E.M.F.—such as in the case of the example quoted above of the Leyden jar charged by an electrical machine—there will be some loss of charge by leakage, this loss taking the form of a leakage current flow through the condenser insulation. If the condenser is charged to a potential of, say, 10,000 volts, and its insulation resistance is only as low as 10 megohms, the leakage current through the dielectric will evidently be—

$$I_l = \frac{V}{R_l} = \frac{10^4}{10^7} = 0{\cdot}001 \text{ ampere.}$$

Such a leak would be a very serious one, and if the condenser potential were maintained it would involve a not inconsiderable expenditure of energy.

This energy loss is—

$$W_l = \frac{V^2}{R_l} = \frac{10^8}{10^7} = 10 \text{ watts.}$$

The whole of this energy would be expended in heating up the dielectric in the condenser, and any other insulation—such as at the terminals, etc.—where the leakage was taking place. Although an energy loss of 10 watts is not much if it is in the open, if it occurs in a closed-up space, as in the dielectric of a condenser, it may lead in a small condenser to a considerable temperature rise. In actual practice the loss should be much less than this figure.

This type of condenser loss is one that is, or may be, encountered in the case of smoothing condensers used in connection with rectifying valves, as at C in Fig. 1, which is the conventional arrangement for "two-wave" rectification. If the rectifying equipment is doing nothing beyond charging the condenser C to a potential of approximately 0·7 V, where V is the R.M.S. voltage across the outer ends of the secondary winding of the transformer T (assuming that the connections are arranged as shown in Fig. 1, with one terminal of the condenser connected

to the mid-point tapping of the transformer secondary), the above source of loss will be the only one when once the condenser has been charged up to the above-mentioned voltage. The energy loss will be as before—

$$W_c = \frac{V_c^2}{R_l} \text{ watts} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

Where W_c = the energy loss due to D.C. leakage, and V_c = the actual voltage across the condenser C.

The extent of this loss can obviously be determined if the insulation resistance of the condenser is known. The value of this quantity R_l which should be used in equation (1) should be determined by measurement with a direct-current voltage of the value V_c under which the condenser will be operating. The reason for this statement is that, with most dielectrics used in commercial condensers the *apparent* value of R_l is by no means constant, but varies with the method of measurement. If the leak is a very serious one across terminal insulators, etc., there will not, as a rule, be such large changes as when the whole of the leakage takes place through the dielectric of the condenser. Some idea as to the extent of this variation may be seen from Fig. 2, which shows the apparent D.C. resistance of a condenser plotted against time as measured from the instant of first application of a charging voltage. Curves are also given in the diagram for different values of the applied charging voltage, as this effect of changing apparent resistance is not independent of the voltage.

The changes in resistance with time are due to the absorption of the charge by the dielectric—an absorption which not only shows itself in this way, but also by the residual charges which are given out by the dielectric after the condenser has been discharged. While the charge is soaking into the dielectric in this manner the current flowing into the condenser is really mainly made up of the charging current which is supplying these absorbed charges, and this current does not, therefore, accurately give

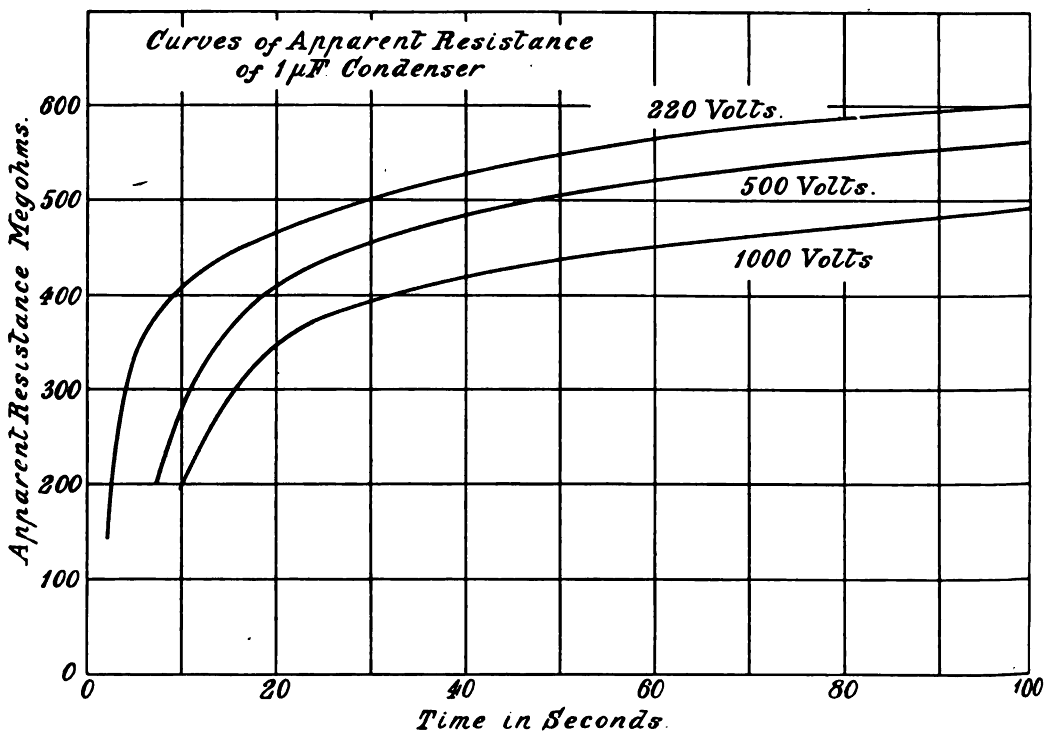


Fig. 2.—Illustrating the apparent resistance of a condenser plotted against time.

any indication of the true insulation resistance of the condenser.

This latter is the value that the apparent resistance takes up after an infinitely long charging period. Expressed otherwise, it is the asymptotic value of the apparent resistance curves of Fig. 2. It is frequently desirable to be able to specify some value of the apparent insulation resistance of a condenser which can be readily determined without the necessity of a véry prolonged charging period, and consequently in many cases the apparent value of the insulation resistance after a charging period of one minute at a certain voltage is specified. Such a definition, while not, of course, giving the true insulation resistance, gives

are usually quite unreliable on account of fluctuations of voltage from the generator.

In actual practice, when a condenser is used for smoothing out the ripples from a rectifying valve circuit for feeding a valve transmitter, the load put upon the smoothing condenser by the oscillator valves prevents the condenser from being charged up to the full no-load voltage, and consequently there is a pulsation of voltage at the condenser terminals. This state of affairs entails additional losses, as compared with what has already been considered. In the first place, the charging time during each pulsation of the charging voltage is small, so that the effective D.C. leakage loss is increased due to the apparent decrease of

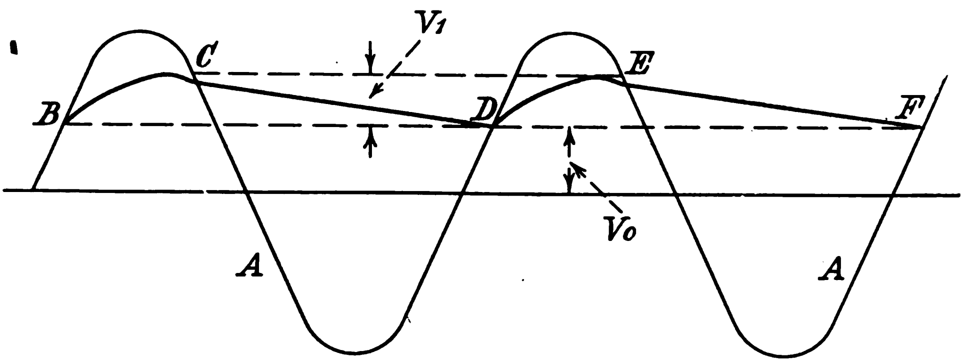


Fig. 3.—Illustrating the condition of a condenser when a sine wave voltage is applied across it.

a figure which can be used for comparison purposes between a number of similar condensers.

In connection with determinations of insulation resistance by measuring the flow of current through the condenser under an impressed D.C. voltage on the lines indicated above, it is desirable to bear in mind the necessity for a truly steady voltage. Any fluctuation of voltage, such as may be due to commutator ripples in a generator supplying the circuit, may cause violent fluctuations in the reading of the microammeter or galvanometer which is used to measure the leakage current, due to the comparatively large currents flowing into or out of the condenser charging or discharging it in accordance with the voltage fluctuations. Such effects may entirely mask the readings which it is desired to obtain. For a similar reason readings taken with an ordinary "megger"

insulation resistance caused thereby. This D.C. leakage loss may thus be regarded as made up of two parts, the first being the steady D.C. leakage loss due to the portion of the rectified voltage which does not pulsate, and the second due to the similar loss arising through the short charging period during each pulsation of the total voltage. Reference to Fig. 3 may make this clearer. In this diagram the sine curve AA is intended to represent the applied voltage, while the curve B, C, D, E, F is the curve of voltage across the condenser terminals assuming single-wave rectification. This latter curve rises during the periods B, C and D, E, during which the condenser is being recharged by the supply at a greater rate than it is being discharged by the load circuit of the oscillator valves.

During the periods C, D and E, F the condenser is not being charged by the supply

circuit, but its potential is falling under the steady discharge of the load circuit. Thus the condenser voltage curve can be regarded as made up of two parts, a steady part of value V_0 and a pulsating part V_1. Hence we may also look upon the D.C. energy loss in the condenser as made up of two parts: the first V_0/R_{I_0}, where R_{I_0} is the true D.C. insulation resistance of the condenser under steady applied voltage V_0, in the sense that has been defined in this article; and the second $V_1^2/4R_{I_t}$, where R_{I_t} is the apparent insulation resistance of the condenser under applied voltage $V_1/2$ for a short time of application of the voltage represented by the period of the A.C. supply, and $V_1/2$ is the mean voltage during this period. This second quantity is one which it is, perhaps, easier to measure than to define, as the determination of R_{I_t} is likely to prove a difficult experimental feat. The effective energy loss could more readily be determined by difference between the total loss and that due to V_0^2/R_{I_t}.

Unfortunately, however, this is not the end of the story, as the determination of this portion of the energy loss by difference, as just indicated, would be likely to give a false value to this quantity, for the reason that other sources of energy loss might be included. Thus, for instance, it is possible to look upon this extra loss in other ways, and to consider it as partly due to the energy loss consequent upon the soaking in and out of the absorbed charges. The cause of the absorption effects which have here been discussed may be looked upon as the charging up of particles of the dielectric material (particles possibly of molecular dimensions) in the interior of the mass of the dielectric, the charges having to filter their way through the molecules of the dielectric in this process. This conduction of the charges into the interior entails an energy loss due to the flow of the charging current through the resistance of the body of the dielectric. As we have seen from the curves in Fig. 2, the magnitude of these charging currents may be much greater than that of the final steady currents through the dielectric, and in consequence the actual energy loss due to them may be correspondingly greater. This may be clearer from Fig. 4, which expresses similar measurements to those plotted in Fig. 2, but in this case given in terms of the current flow through the condenser dielectric.

The magnitude of this source of energy loss will evidently depend upon the frequency of the pulsations of voltage applied to the condenser, for each time the condenser is charged and discharged these absorption charge currents must flow into and out of the dielectric. Hence, on this basis, this loss will increase approximately in proportion to the frequency. As the frequency is raised, however, another effect begins to come into play. We have seen that this absorption of the charges is a process requiring time, and therefore it follows that if the actual charging period is very short (as must necessarily be the case if the frequency of the charges and discharges becomes large) less charge will be absorbed than would be the case for longer charging times.

At ordinary commercial supply circuit frequencies this reduction of the absorption effect does not seem to be very pronounced, but there is evidence indicating that for the higher frequencies there is a marked reduction in the absorption, so much so that the reduction of absorption may overtake the increase of loss due to the higher frequency, with the result that there is a nett *reduction of loss* at very high frequencies. The experimental difficulties surrounding measurements of this nature render an exact determination of these changes by no means easy, but at least in the case of some materials which show considerable absorption losses at comparatively low frequencies (in the neighbourhood of 1,000 ∽) there is certainly much less loss due to this cause when they are subjected to radio-frequency voltage pulsations.

This effect may perhaps more simply be expressed by saying that at radio frequencies there is *no time* for the charges to soak into the material, with the result that, under these conditions, the materials behave as much more perfect dielectrics. Whether these results are truly general for all dielectrics, or are confined to a few only, can only be settled by exhaustive experimental investigations.

Still another effect needs consideration if the voltage pulsation (V_1 in Fig. 3) is of any considerable amplitude on a condenser used for smoothing purposes with a valve rectifier. This is the A.C. energy loss in the condenser dielectric due to the voltage pulsations. The

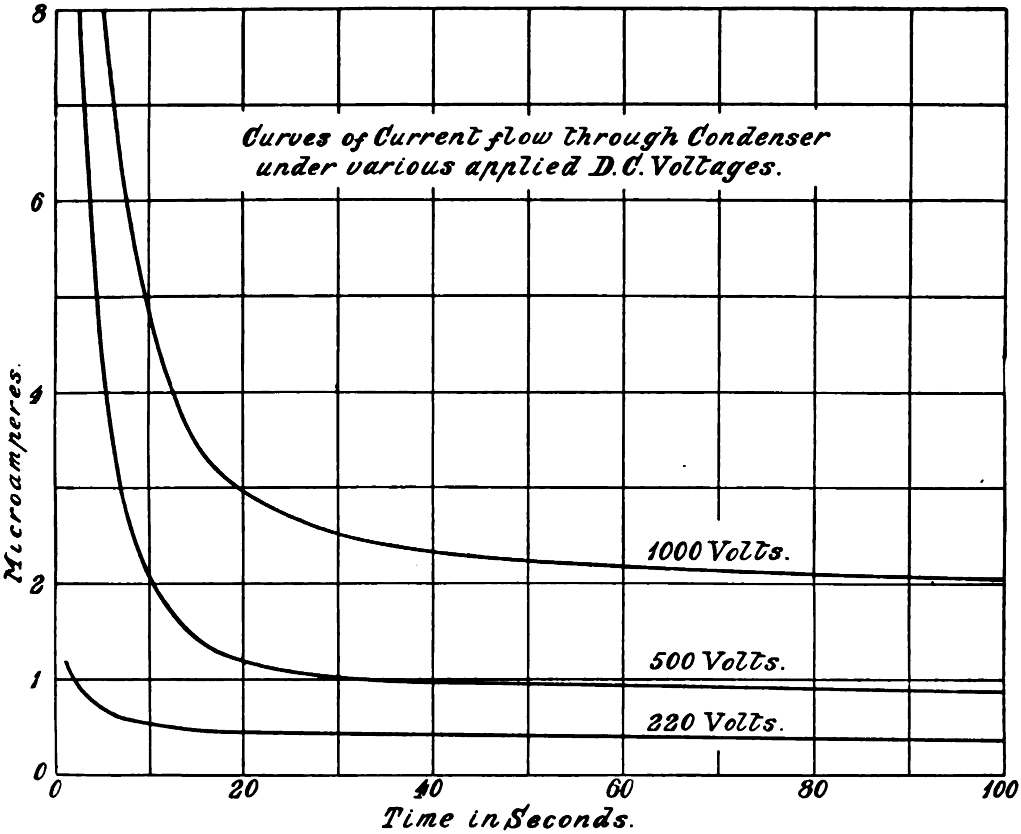


Fig. 4.—Showing how the current through a condenser at various voltages varies with the time.

application of an E.M.F. between the plates of a condenser implies that the condenser dielectric is subjected to a mechanical strain as well as to an electrical one. This strain will be of an alternating or pulsating nature, depending upon the type of potential variations to which the condenser is subjected. In a condenser built up of a stack of alternate sheets of tinfoil and paper fastened together with a suitable binding, such as of tape, it is quite possible to obtain audible evidence of these mechanical strains. By applying an alternating E.M.F. to such a condenser the varying attractions and repulsions between the condenser plates set up an actual mechanical vibration of the electrode plates, which will give rise to a sound if the A.C. frequency is a suitable one. Such mechanical stressing of the dielectric and mechanical vibration of the electrode plates entails the expenditure of energy, which, since it is drawn from the electrical circuit in which the condenser is connected, represents another source of energy loss in the condenser.

In a properly designed condenser this loss should be a very small one, but its magnitude will depend very greatly upon the nature of the material used for the dielectric, and upon the method employed for the construction of the condenser.

To summarise, then, the main energy loss in a condenser used for D.C. smoothing purposes may be regarded as made up of three parts :—

(1) The leakage loss W_l, which may itself be resolved into two components—

$$W_l = V_0^2/R_{l_0} + V_1^2/4R_{l_1} \quad \text{.....................} \quad (1a)$$

(2) The absorption loss W_a, which may be written—

$$W_a = V f(n) \quad \text{.......................................} \quad (2)$$

(3) The vibration loss due to voltage pulsation—

$$W' = f_v\,(V_1^2 n) \quad \ldots\ldots\ldots\ldots \quad (3)$$

So that we may therefore write—

$$W_{d.c.} = W_l + W_a + W_v \quad \ldots\ldots\ldots\ldots \quad (4)$$

The exact type of the functions expressed by f and f' will vary with different dielectrics, and probably also with the numerical magnitude of the frequency, as has already been indicated. The vibration loss W_v has been put down as a function of V_1^2 (where V_1 is the applied pulsating voltage), since the mechanical attraction between the oppositely charged plates will thus vary with the voltage between them.

In a badly constructed condenser there may also be some small additional loss due to the flow of the charging currents through the conducting plates themselves, but this loss should be negligible in a condenser used solely for smoothing purposes. It may become serious in some cases when the condenser is carrying considerable high-frequency currents, but this case will be considered in a later section.

(To be continued.)

Artificial Aerials.

MANY applicants for transmitting licences have received from the P.M.G. authority to transmit on a non-radiating artificial aerial circuit, and consequently a few notes on artificial aerial working will no doubt be of interest. The artificial aerial is defined as a closed non-earthed oscillatory circuit containing inductance, capacity and resistance. Now many amateurs say on receiving such a licence that this is not any use to them. However, if any experimental work is really intended, a great deal can be done. I consider that my own most useful work has been accomplished with an artificial aerial, and many others will agree that they find it of equal use.

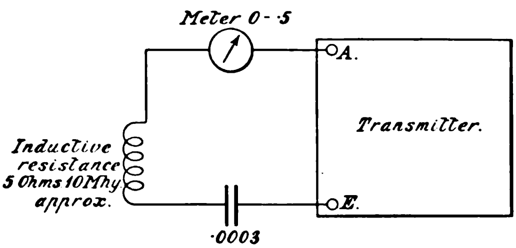


Fig. 1—Showing the connections of the artificial aerials to the transmitter.

The artificial aerial is so called because it is a closed circuit which is intended to shunt the aerial earth terminals of the transmitter, thereby replacing the aerial earth system. It is meant to have just the same characteristics as an outside aerial, so that on replacing one by the other the operation of the transmitter is not interfered with in any way. The usual amateur aerial constants are approximately as follows:—Capacity ·0003 mfd., resistance, say 10 ohms, inductance 10 mhys. These figures of course really only apply to one particular wave length, but serve as a guide for a suitable circuit. If a ·5 amp. max. aerial current meter (hot-wire) is used we have in this a resistance of say, 5 ohms. The other 5 or so ohms can be made of about No. 30 S.W.G. Eureka on a 2-in. former, which will provide a small inductance to suit the conditions. The condenser should be as good a one as possible. Two or three large copper or brass plates carefully air-spaced and made nearly self-supporting, so that little insulation is needed, will be found very satisfactory. These three components are connected in series all across the transmitter output terminals. The transmitter is then adjusted in the normal way as if the usual aerial and earth system were connected to the transmitter. The efficiency of the set can be found as the resistance of the artificial circuit is known and also the current in it (see EXPERIMENTAL WIRELESS No. 1, Efficient Transmission).

By using such a circuit as this a great deal of useful information may be obtained, and I hope that many will now conduct some of their testing on artificial circuits so as to leave a clearer ether for others who have experiments which of necessity have to be carried out on a radiating aerial.

"2 SH."

The Design and Construction of Filters.

By FREDERIC L. HOGG (2SH).

The design of a smoothing circuit seems to be a subject which presents considerable difficulty when the frequency is rather low. Many amateur experimenters spoil their telephony by generator hum, and it is hoped that the following article will help in the solution of the problem.

In radiophone transmitters it is essential that the anode voltage supply should be perfectly pure D.C. Now, when this supply is obtained from a D.C. generator or from rectified A.C. there is a considerable ripple on the steady D.C. voltage which

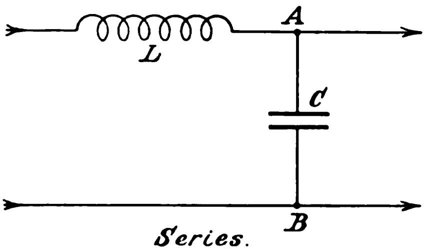


Fig. 1(a)—A series resonant circuit.

completely spoils any telephony. The usual procedure in amateur stations is to grab hold of half a dozen old spark coils and Mansbridge condensers and hope for the best. Needless to say, the best is usually the worst. It

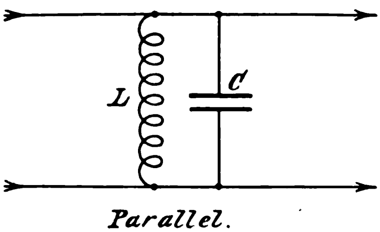


Fig. 1(b)—A parallel resonant circuit.

would not be far out to say that there are probably not more than half a dozen amateurs using A.C. for their 'phone sets whose smoothing is absolutely perfect in this country. In this article it is proposed to deal with the design and construction of wave filters from the amateurs' standpoint.

An electric filter is an apparatus which enables us to separate into its various parts an electric current made up of a combination of different frequencies. For instance, a small condenser of, say, ·001 mfd. will discriminate between a radio-frequency current of 1,500,000 ∽ and a speech frequency of 800 ∽. The action of an inductance is the reverse. The simplest practical filter is a resonant circuit across the supply, either series or parallel (see Fig. 1). If we apply an A.C. voltage to

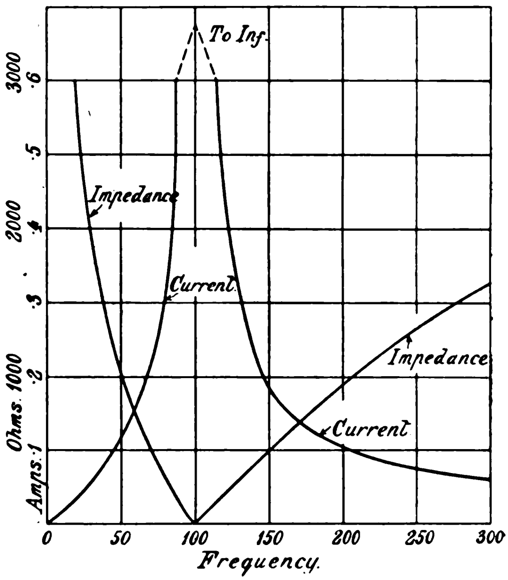


Fig. 2—Illustrating the relation between current and frequency applied to a series circuit.

one of these circuits, and vary the frequency, we find that in the series circuit the current will increase as we increase the frequency up to a certain point, and then will fall off again on further increase (see Fig. 2). The impedance or effective resistance is shown also in Fig. 2. It will be seen that the impedance and current are respectively at minimum and maximum at a certain point. This is called the resonance point. For a parallel circuit we get just the reverse of

what a series circuit gives us. In these cases we have assumed that the filter is of infinitely low resistance. We will now investigate the case when the filter contains a resistance, or, in other words, has a load taken from it. Let us consider, again, the series circuit. We take our load across A, B. The effects of various loads are shown in the diagram (Fig. 3). From elementary A.C. theory the voltage across the condenser will be :—

$$e = \frac{E}{\sqrt{\left[1-(2\pi f)^2 LC\right] + \left[\frac{2\pi f L}{R}\right]^2}}$$

Where E is the supply voltage, f its frequency, and L, C and R the constants of the circuit.

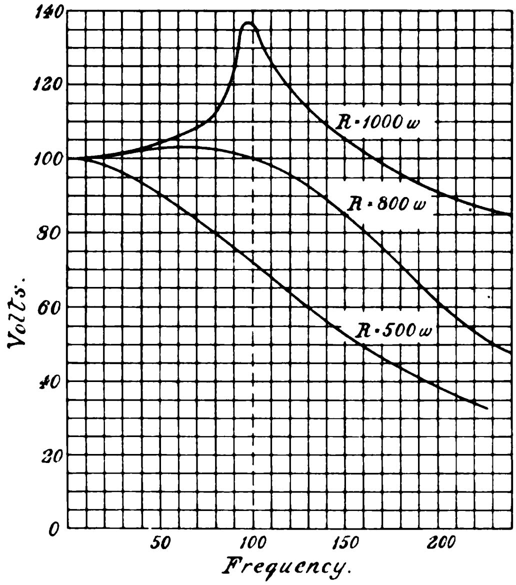


Fig. 3—Illustrating the effect of various loads applied to a series filter.

In the diagram the curves have been worked out for E=100 volts, L=1 henry, C=1 mfd., and R 1,000, 800 and 500 ohms. It will be seen that any filter works best for a particular load. This difficulty, however, does not arise very much in practice, except when a small filter is overloaded. However, it must not be overlooked in building a filter. Now, it will be seen that this series circuit will transmit current below a certain frequency, and above this frequency the current rapidly diminishes, or, rather, the circuit increases

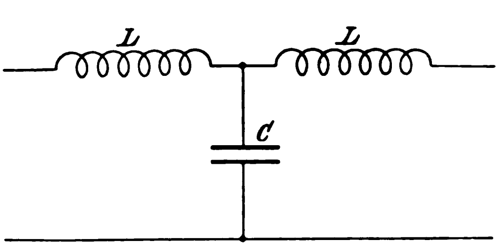


Fig. 4—An inductance is connected in series with the load.

in resistance and so cuts down the current. This type of circuit is known as a " low-pass " filter. It will be obvious that if we put the load across the inductance we should get the reverse effect, and this is really, in effect, a parallel circuit. This type is known as a " high-pass " filter.

The simple series circuit mentioned above does not give a very sharp separation of frequencies. This can be improved con-

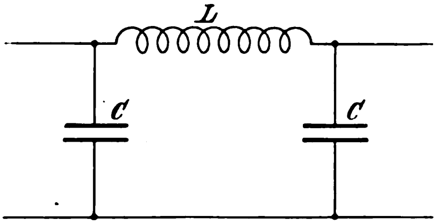


Fig. 5—The " π " type of filter.

siderably by inserting an inductance in series with the load. This is called a T section (Fig. 4). If we were to re-draw Fig. 3 for this section we should find that the cut-off would be very much sharper, and that it would be moved to 141 ∽ ($100 \times \sqrt{2}$). Also for heavy loads it would be found that the voltage first falls and then rises again to normal at the cut-off frequency, falling once more as the frequency rises. Note that the two inductances have the same values. In all types of filters the inductances or condensers should all be of the same size except the end sections, which should

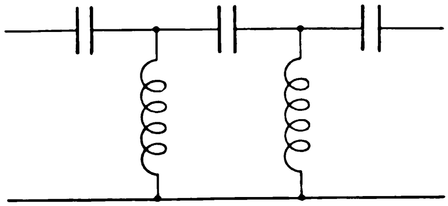


Fig. 6—A " high pass " filter circuit.

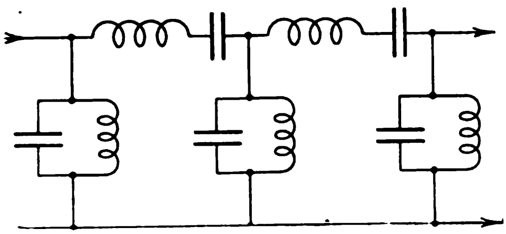


Fig. 7—A "band-pass" filter circuit.

be of half the capacity or inductance as the case may be. The reason for this is fairly obvious. The addition of further sections to the filter will have the effect of sharpening the cut-off and increasing the number of maxima and minima in the portion of the curve before the cut-off frequency.

Another type of section is the π. This is shown in Fig. 5. The same remarks apply here. Now, we can build either a filter which will pass all below a certain frequency, and, under the same conditions, one which

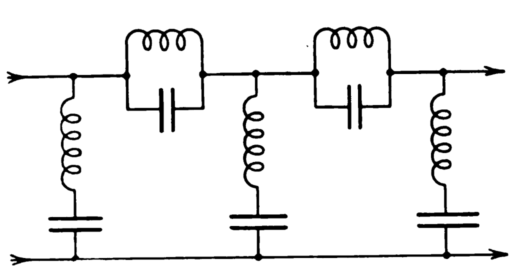


Fig. 8—A "band-elimination" filter circuit.

will have the reverse effect. Now, if we insert a low-pass filter in our line, cutting off at, say, 200 ∽, and follow this up by a high-pass filter with a cut off of 100 ∽, we should get what is known as a band-pass filter, passing all frequencies between 100 and 200 ∽, and by reversing the cut-off frequencies we get a filter of the band elimination type between 100 and 200 ∽. However, as we are only interested in the low-pass type, no further mention of the others will be made. Figs. 6, 7 and 8 show

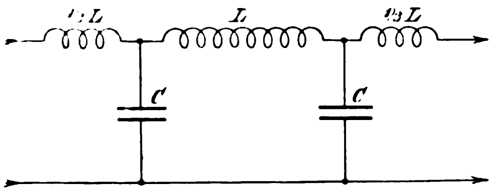


Fig. 9—A two-section T type filter.

complete high-pass band-pass and band-elimination filters respectively.

To get to the more particular design of low-pass filters, the simple T and π types dealt with above will give us a fairly gradual cut-off, but the attenuation increases with the frequency, *i.e.*, they become better and better as filters. Now, by inserting resonant circuits in series with or across the line we can make our filter give us a very sharp cut-off, but the attenuation will decrease as the frequency rises. Thus we could make a filter of this type to cut off at 100 ∽

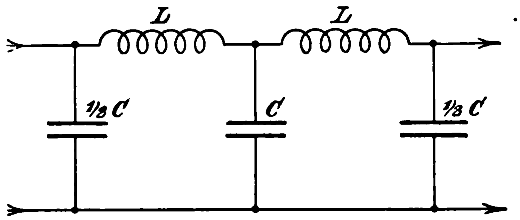


Fig. 10—A two section π type filter.

and give maximum attenuation at 120 ∽ for some special purpose. The calculations in the design are rather complicated, and would be of little use, so will not be given here. Figs. 9 and 10 show two-section T and π filters giving distribution of inductance L and capacity C.

To find L and C for any particular set of conditions, if Z is the resistance of the load

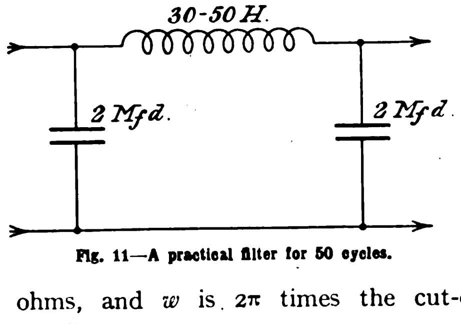


Fig. 11—A practical filter for 50 cycles.

in ohms, and w is 2π times the cut-off frequency—

$$L = \frac{2Z}{w} \quad \text{and} \quad C = \frac{2}{wZ}$$

Z would be the effective internal resistance of the valve in the cases we are considering, or the total resistance of one or more in parallel. This would be given by $\frac{\text{anode volts}}{\text{anode current}}$ when actually working, and not the steady

internal resistance value, as the valve is oscillating and is transferring energy to the aerial circuit. In designing a filter for an experimental set the filter should be of generous dimensions, as a large filter on low power is better than a small filter on high power.

filter such as Fig. 13 will really filter and give almost perfect D.C. under the most stringent tests. Values are shown against the various components.

The average amateur will say, perhaps, that he has already 50 to 100 henries for his filter. But, unfortunately, iron core

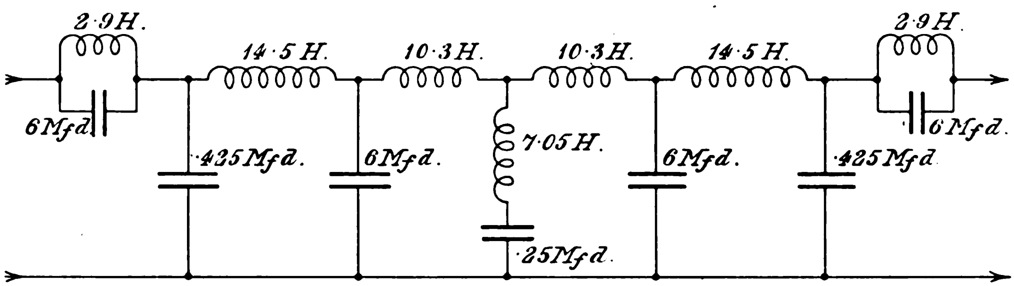


Fig. 12—Illustrating the arrangement of a correctly designed filter circuit for 50 cycles.

In our case, when we are dealing principally with rectified A.C., we can take our wave form as consisting of a large number of harmonics, or we can consider it as wave in which there are gaps to be filled in! In the first case a certain amount of brain is used, whereas in the second we get D.C. because the A.C. cannot help itself when we put huge capacities and inductances in. A filter for 50 ∿ A.C. should be designed to cut-off at about 20 ∿. It will be found,

chokes must be designed just as much as anything else. First of all, a closed core choke must not be used. A closed core fosters the harmonics and often does more harm than good. Also if care is not taken the steady D.C. current present will saturate the core. The choke should be made with a small air gap and sufficient iron to ensure that it is never near saturation. A good transformer iron, preferably stalloy, about ·015 in. thick, should be used. Fig. 14 shows

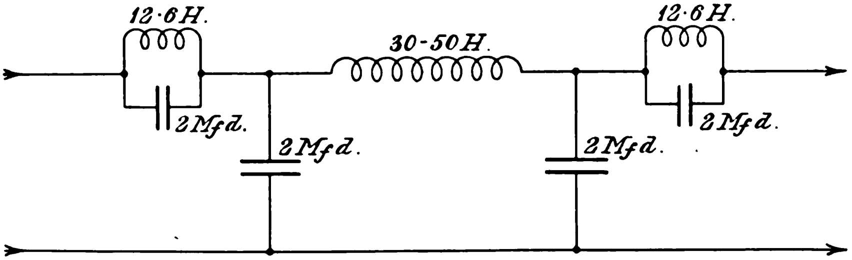


Fig. 13—A resultant filter which is a modification of Figs. 11 and 12, two tuned traps being inserted.

unfortunately or fortunately, whichever way you look at it, that dealing with the irregular wave forms which we get the "brutal" method is best, though a judicious combination of both helps. For an average set Fig. 11 gives an excellent filter. Fig. 12 gives a most excellent design, but works not quite so well as Fig. 11! An improvement can be made by inserting a few tuned traps, and a

type of core and windings. All the wire should be placed on one limb, and the two ends should be butt-jointed instead of lapped. The other limb must be adjustable and rigidly fixable in any position. The table gives sizes of core (square) and other details for various currents and inductances:

"X" and "Y" are the actual dimensions of space occupied by wire. ¼ in. or more space must be left for cheeks, according to

size, so that the length of longer laminations will be X+(depth of core)+¼ to ½ in. space for cheeks. Enamelled wire is quite suitable, but the winding must be well insulated from the core. On the larger sizes a layer of waxed paper should be placed over every few layers. The inductance can be varied by adjusting the air gap or by changing the number of turns. It must be borne in mind that the inductance will vary approximately as the square of the number of turns. The air-gap figures are meant merely to indicate the order of magnitude of the gap. It should be varied for best results. A good method of testing is to put a loud speaker in series with a good ·001 condenser across the output on load and to vary chokes, etc., till hum is least. Don't use a pair of 'phones and wear them. If you use 1,500 volts or so a shock on the head is unpleasant, to say the least of it; and if you use 2,500 volts or so your filter will be no use to you, however good it is, because you would probably be dead! Care must be taken to clamp the iron core choke very tightly so that the air gap cannot alter. Considerable force exists in such a choke. When choke control is used for telephony it is best to use another choke in the positive lead apart from the usual filter chokes. The size of choke necessary is given by—

Current amp.	Henries.	Air Gap. in.	Turns.	S.W.G.	X. in.	Y. in.	Core. in.	Volt Drop.
·05	1	1/64	2,300		·5	·33	½×½	7
·05	5	1/40	3,500		·62	·42	¾×¾	14
·05	10	1/32	3,800	36	·64	·43	1×1	18
·05	20	3/64	5,700		·78	·52	1×1	29
·05	50	7/64	11,000		1·10	·75	1×1	64
·05	100	¼	8,900		·97	·65	2×2	76
·1	1	1/50	1,500		·53	·37	¾×¾	6
·1	5	1/40	2,600		·71	·49	1×1	14
·1	10	1/32	1,900	33	·60	·42	2×2	16
·1	20	3/64	2,900		·75	·51	2×2	26
·1	50	7/64	5,300		1·00	·70	2×2	50
·1	100	⅛	8,900		1·33	·90	2×2	90
·25	1	1/50	1,100		·75	·5	1×1	6
·25	5	¼	1,300		·82	·53	2×2	10
·25	10	5/16	1,300		·82	·53	3×3	16
·25	20	3/64	1,900	27	1·00	·65	3×3	24
·25	50	1/3	5,000		1·60	1·1	3×3	70
·25	100	19/32	8,400		2·1	1·4	3×3	120

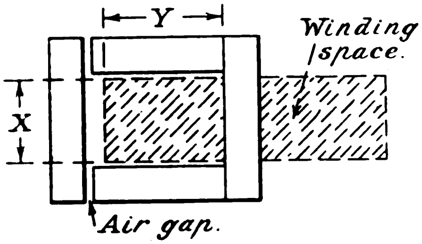


Fig. 14—Constructional details of a smoothing choke.

$$L = \frac{E}{2\pi f I},$$

where E = anode volts,
I = anode current,
f = mean speech frequency,
= 800 ∽,

though usually about 10–20 henries is found sufficient for all-round purposes. This can be designed from the tables given above.

In this short article it has only been possible to touch on a few points of the subject, but I hope sufficient information will be found herein to enable anyone to get rid of any ripple in his plate supply. If but one of the stations who appear to do telephony on raw A.C. is cured of trouble I am satisfied!

The Construction and Manipulation of Wavemeters.

Readers may have noticed that in Fig. 7, Page 74, showing the wiring lay-out of a heterodyne wavemeter, the positive and negative poles of the high tension battery were shown reversed. This point should be remembered when making the instrument.

Notes on High Tension Electrolytic Rectifiers.

B. E. H. ROBINSON (2VW).

As the chemical rectifier is now used for obtaining the high anode voltage for transmission purposes by many experimenters, it is thought that the following notes by one who was the first to develop it in these directions will be of considerable value.

IN an issue of the *Wireless World and Radio Review* last December the writer described an aluminium electrolytic rectifier suitable for rectifying high-voltage currents to produce D.C. suitable for valve transmitters. Since then a number of inquiries for further details have been received concerning the construction and working of such rectifiers and in view of the fact that many experimenters are now adopting this method of obtaining their H.T. supply the following notes may be found useful.

Suitable A.C. Frequency.

In the first place it should be noted that the electrolytic rectifier is only suitable to work on an alternating current supply whose periodicity does not exceed about 120 cycles per second. A certain amount of rectification may be obtained on periodicities up to 200 but not much higher, as the rectification becomes extremely poor. Electrolytic rectifiers cannot be used with 500 cycle supplies such as are obtained from some Disposals Board alternators. Similarly there is no hope of using electrolytic rectifiers with a T.V.T. unit, as such units give an unsuitable wave form at too high a frequency.

Electrolytic rectifiers work best on sinusoidal A.C. at the usual commercial frequencies between 50 and 90 cycles per second. On these low frequencies very good results may be obtained at quite a favourable overall efficiency.

Electrodes.

For the cathodes of the rectifier cells aluminium is almost invariably used, and as it is at the surface of the aluminium that all the rectification takes place, too much attention cannot be given to the proper design and maintenance of these aluminium electrodes. In the original Nodon valve the aluminium was alloyed with a certain amount of zinc or other metal, but ordinary commercial sheet aluminium is quite suitable provided that it is properly cleaned. It is a good plan thoroughly to clean the surface of the aluminium electrodes the last thing before mounting them *in situ* in the rectifier cells. This may be done by immersing them in a solution of caustic soda for about ten minutes or until the surfaces are slightly but uniformly corroded; they are rinsed free from caustic soda, drained and immersed in strong nitric acid for a few minutes. Nitric acid attacks practically all impurities, but not the aluminium, so that after a second thorough rinsing in clean water the aluminium should have a matt silvery-white appearance.

The actual metal used as anode in the cells is not very important as its only function is to make contact with the electrolyte and takes no part in the rectifying action. The only important thing is that the anode should not be attacked by the electrolyte. The most common substances used are iron, carbon, tin and lead, the latter being the best from practical considerations. Iron shows a tendency to slow corrosion when ammonium salts are used for the solution, whereas lead is absolutely permanent. In use a brown deposit of lead peroxide forms on the surface of the lead, but this does not appear to be in any way detrimental.

The Electrolyte.

The choice of electrolyte is one of the most important factors. A number of neutral salts give solutions in which an aluminium electrode shows a rectifying action to a greater or less extent, but only a few salts combine efficient rectification with clean working. Of these, pure ammonium phosphate is one of the most readily procurable and, in the writer's experience, the most efficient. Sodium phosphate is con-

siderably cheaper and gives fair results, but is distinctly inferior to the ammonium salt. When the ammonium phosphate is used care should be taken that the solution does not give acid reaction ; it should be neutral, or, if anything, very slightly alkaline. The cheaper commercial grades of ammonium phosphate are apt sometimes to be rather strongly acid. It is therefore advisable to buy the pure phosphate if the extra expense is not objected to. Even the latter is sometimes strongly enough acid to turn a piece of blue litmus paper red, and when this is found to be the case the solution should be rendered neutral before using. This may be done by adding either some strong ammonia solution (sp. gr. ·880), or a

properties of the surface. Also a saturated solution seems to favour the formation of sludge and colloidal aluminium hydroxide more than a weaker solution does.

The following data about sodium and ammonium phosphates are useful when solutions are being made up.

AMMONIUM PHOSPHATE.

Chemical formula of the salt manufactured commercially $(NH_4)_2HPO_4$.

Solubility :—One part in four parts of water (by weight).

Weight of ammonium phosphate required for half-saturated solution is

125 gms. per litre of water, or

2½ ounces per pint (very nearly).

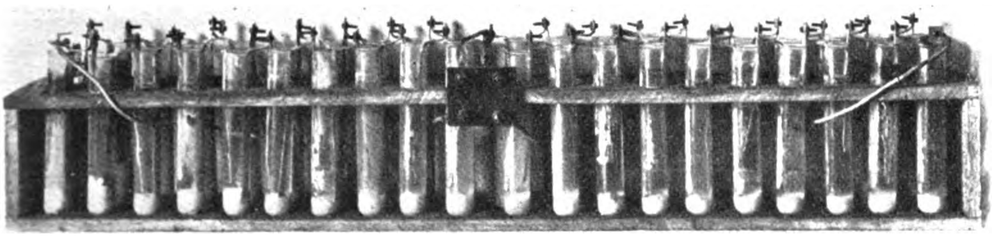


Fig. 1.—An electrolytic rectifier, employing the connections shown in Fig. 3, capable of delivering 50 milliamps. at 1,000 volts of full cycle rectified D.C. The small quantity of sediment which forms at the bottom of the cells does not matter as long as it does not reach the aluminium strips.

half-saturated solution of sodium phosphate, and stirring until the phosphate solution will just turn a piece of red litmus paper blue. If the neutralising is done with sodium phosphate the solution obtained will, of course, contain a mixture of the two phosphates, but this is found to work quite well.

With regard to the strength of solution the writer recommends that whichever salt is used as electrolyte the solution should be half or three-quarters saturated. The frequent practice of using a fully saturated solution is not to be recommended because as soon as a little of the water in the solution evaporates some of the dissolved salt crystallises out, the crystals not infrequently forming on the aluminium surfaces, thereby causing leakage and spoiling the rectifying

SODIUM PHOSPHATE.

Formula of commercially manufactured salt $Na_3PO_4.12H_2O$.

Solubility one part in five parts of water (by weight).

Weight of sodium phosphate crystals to make a half-saturated solution—

100 gms. per litre of water, or

2 ounces per pint.

In comparing the performance of sodium and ammonium phosphates it is interesting to note that sodium phosphate becomes strongly alkaline after continued use whereas ammonium phosphate tends to lose ammonia and become acid. Partially used sodium phosphate is found often to contain free caustic soda, which accounts for the fact

that the rectification degenerates and the aluminium becomes corroded when this salt is used. This does not seem to happen with ammonium phosphate.

Other electrolytes than the two mentioned above may be used, but none seem to surpass ammonium phosphate. Sodium bicarbonate and borax are two commonly recommended substitutes. Borax, in particular, is frequently recommended in American periodicals for high-tension rectifiers, but the writer has tried it several times and found it hopeless. In the first place, boron is only sparingly soluble in water and forms a comparatively poorly conducting solution. Secondly, the rectification is not particularly good and the borax tends to crystallise out on to the aluminium electrodes. Even if

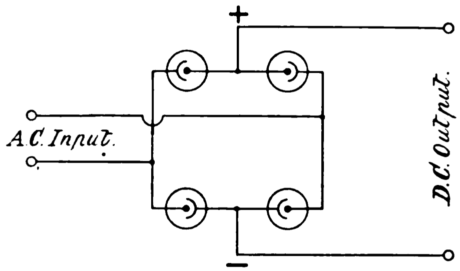


Fig. 2.—Showing the Gratz connections for full-cycle rectification.

the freshly made up cell rectifies the aluminium becomes covered in a short time with an incrustation of goodness knows what, and the rectified output goes down to a negligible quantity. Similar remarks apply of sodium bicarbonate.

Voltages and Currents Allowable.

If a rectifier cell is connected in series with an ammeter across a source of direct current quite a large current will be registered when the supply is connected so as to make the current pass from lead to aluminium. On reversing cell, however, so as to make the current pass from aluminium to lead only a very small current flows. This reverse current may be only a few milliamperes when the voltage of the D.C. source does not exceed about 150 volts. If the applied voltage is raised much above 200 the insulating film which is formed on the submerged surface of the aluminium begins to break down, the cell heats up and passes a large current. A very good cell may hold up against 240 volts of reverse e.m.f. for quite a considerable period. For rectifying 50 or 60 cycles A.C. such high voltage should not be allowed per cell. A good working basis is to allow 100 volts per cell of A.C. That is, if we wish to rectify 1,000 volts (R.M.S.) A.C. input with the four-group (Gratz) connections we should have ten cells in each group to sub-divide the potential strain. As a matter of fact it has been found that when in good condition rectifier cells will often work quite happily at 120 to 140 volts apiece without unduly large back currents occurring. The higher the voltage that can be allowed per cell the less will be the total number of cells required and the higher will be the overall efficiency of the rectifier, provided always that heating and excessive reverse currents are not set up. Owing to the fact that aluminium electrolytic rectifiers show a maximum efficiency when working at about 100 volts per cell they are more satisfactory for high-tension low current work than for large currents at only a few volts as in accumulator charging. Thus the fact that the rectifier has rather fallen into discredit for battery charging should not unduly bias our opinion when judging it for H.T. purposes.

The size of the aluminium electrodes should be properly proportioned to the current which is to be rectified. If the surface area is too big the current density will be small and the electrodes will not polarise rapidly enough to keep out reverse currents. An analogy may be drawn with a pump whose valves are too sluggish to act if the plunger is moved too gently. If, on the other hand, the surface area is too small the resistance of the cell in the right direction will be too high and sufficient output will not be obtained. The correct current density is about 5 milliamps. per square centimetre of submerged aluminium surface; this includes both back and front surfaces in the case of flat strips or plates. For rectifiers to deal with very small currents such as are wanted for receiving H.T. supply or for transmission on powers below 5 watts aluminium wire of about No. 14 gauge may be used with satisfactory results. For powers of 10 watts or over it is more satisfactory to use strip electrodes cut from aluminium and lead sheets. The aluminium should be as thick as can be conveniently cut with a pair of metal shears. Aluminium

and lead strips may be connected together in pairs by drilling or punching holes at their upper ends and clamping with small bolts and nuts. Fig. 1 clearly illustrates the method of assembly. As at two points (output) there are lead-to-lead and aluminium-to-aluminium connections extra long strips of lead and aluminium are bent over to may the two adjacent electrodes without the necessity of clamping two separate pieces together.

The rectifier shown in the diagram will readily deliver 50 milliamps. of D.C. (full cycle rectification) at a voltage of 900 to 1,000, this being much more than is required by the 10-watt transmitter.

When heating occurs the hot electrolyte rises to the surface and it is just where the aluminium enters the solution that the most rapid corrosion occurs ; bad electrical leakage frequently occurs here also. This trouble is often met by sheathing the aluminium with a piece of tightly-fitting rubber tubing over the parts which extend above and about half-an-inch immediately below the surface of the solution. It is simpler, however, to float about an inch of paraffin oil on the surface of the solution. The writer has always found this effective, and it serves materially to prevent "creeping" and evaporation.

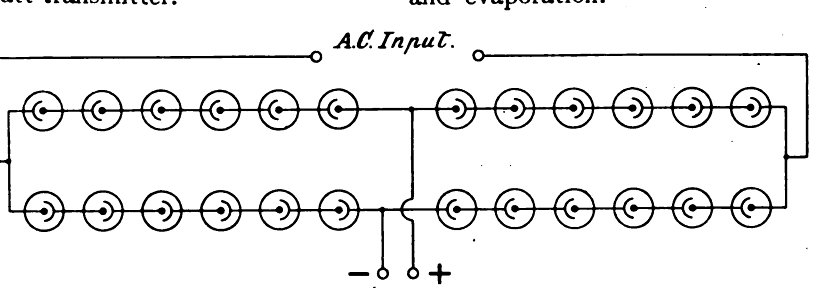


Fig. 3.– Showing how the old Gratz connections are modified to handle voltages above 100. Allow one cell for every 100 volts in each of the four groups.

One of the chief limitations of the load which may be put on to such a rectifier is the heating up of the electrolyte. The only simple practical remedy is to make the cells of ample size so that the bulk of liquid is too great to allow any serious rise in temperature at the normal working current. On no account should the temperature be allowed to exceed 40° C. as the rectification is very poor above this temperature and there is a marked tendency for the aluminium to be corroded, with the consequent formation of a precipitate of aluminium hydroxide. The rectifier shown in the photograph employs large test tubes ("boiling tubes"), 6 inches long by 1 inch diameter, which are filled within an inch of the top with half-saturated ammonium phosphate solution. The cells get just slightly warm when run on a load of 40 milliamps. for about half an hour. On smaller loads the rectifier may be run indefinitely. Very small rectifiers to handle a few milliamps. for reception purposes may be quite satisfactorily made up in the ordinary $\frac{5}{8}'' \times 5\frac{1}{2}''$ test-tubes.

"Forming" the Electrodes.

A freshly made up electrolytic rectifier seldom rectifies immediately the A.C. input is first applied, but the cells may for a time pass a heavy current in both directions. It seems as if some "forming" process with the aluminium electrodes is necessary before the proper rectifying action sets in. For this reason it is not advisable to put a new rectifier straight across the full high-tension voltage, but the voltage should be cut down to begin with or a safety resistance inserted in series with the supply. Usually a rectifier forms nearly completely after the current has been passing for about a quarter of an hour, after which period full voltage may be applied. Sometimes, however, the rectifier proves more refractory and a more drastic method of gingering up the cells must be resorted to. The following plan is very effective where 200-volt D.C. mains are available. Each cell in turn is connected in series with a high-consumption lamp (about 1 amp. normal rating) across the 200-volt D.C. mains with the aluminium

electrode connected to the positive main lead. If, on switching on, the aluminium is not formed the lamp will light up and a relatively large current will pass through the cell. As the aluminium surface forms the current drops rapidly and the lamp goes out and if the cell is a good one the current will fall to a negligible value. If the cell is a dud the lamp will remain alight and the solution will get hot and if on several successive tests the cell still refuses to form it may be taken that either the solution is at fault or the aluminium requires chemically cleaning as described above. If only A.C. is available put two aluminiums in opposition in one cell and apply about 120 volts in series with a lamp; this tests two aluminiums at once. In the event of there being only a 220 A.C. supply available two test cells will have to be treated in series at a time.

If each cell has responded properly to this method of gingering up the rectifier as a whole should at once work satisfactorily off the normal high-tension A.C. supply.

Once a rectifier is properly formed it should work for weeks without further attention, provided that it is not unduly overloaded.

Sometimes it is found that a cell refuses to rectify owing to a grey or black deposit which forms on the surface of the aluminium.

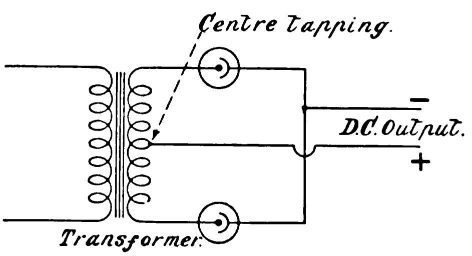


Fig. 4.—Connections for obtaining full-cycle rectification, using a centre-tapped transformer.

Strong nitric acid will usually clean this off without the previous use of caustic soda. Aluminium electrodes that are doing their work properly always have a very clean white appearance.

Indications of Correct Working.

If an electrolytic rectifier is viewed in the dark when connected across the H.T. transformer but with no load across the D.C. output a luminosity is seen on the submerged surfaces of the aluminiums. Under ideal circumstances this takes the form of a uniform glow, but more frequently it has a sparkling appearance not unlike a starry sky on a very clear night. This scintillation is no cause for great anxiety—it only shows that the cell is functioning well and is, perhaps, working near its voltage limit. It is the cells that show no luminosity in the dark that are the black sheep in the fold; in these either the solution is impure

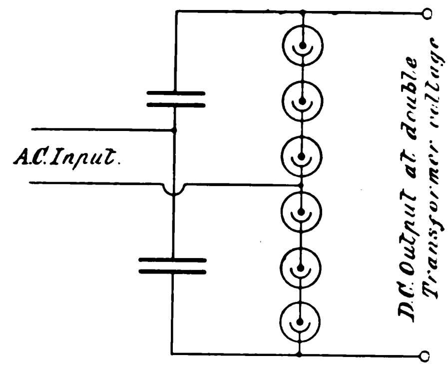


Fig. 5—Double condenser connections for full-cycle rectification. A doubling of voltage is obtained.

or the aluminium needs forming or cleaning. It not infrequently occurs that all the cells in a set are made up at the same time and under apparently identical conditions, yet after a short period of working some of the cells refuse to rectify while others work well. This is due, no doubt, to contamination on parts of the original sheet of aluminium from which the electrodes were cut, and the remedy has already been indicated.

It is important that the bolts which hold adjacent strips together should be well away from the surface of the electrolyte.

Various Rectifier Connections.

It is always worth while to use full-cycle rectification in preference to half-cycle as a higher output is obtainable for a given transformer voltage and it is very much easier to smooth the D.C. output from a full-cycle rectifier. Half-cycle rectified 50-period A.C. gives a ripple frequency of 50, whereas full-cycle rectification gives a ripple frequency of 100. Other things being equal, the higher the ripple frequency the more easily is it smoothed out with chokes and condensers.

Fig. 2 shows the original four-cell or Gratz connections for full-cycle rectification as used for accumulator charging with large-capacity rectifier cells. Fig. 3 shows how these connections are modified for high-tension purposes by replacing each of the cells in Fig. 2 by a bank of cells in series. This system of connections is used in the rectifier shown in Fig. 1 and is very satisfactory for general purposes.

Fig. 4 shows the centre-tapped transformer arrangement which is well known and does not call for much comment. It is well to note, however, that although only half the number of cells is required to give the same voltage as the arrangement in Fig. 3, it has the practical disadvantage that a special transformer is needed with twice the number of turns required in the ordinary way. Thus if one is working on 1,000 volts each half of the transformer secondary in Fig. 4 must each give 1,000 volts, the total voltage between the outer ends being 2,000 volts. Thus not only is it necessary to use twice the amount of wire in the secondary, but it is necessary to insulate for 2,000 volts instead of 1,000. Readers who have attempted to make efficient H.T. transformers will agree that the task of getting well-insulated secondary into the small space available is one which does not admit of unnecessary magnification.

Fig. 5 is one of the most ingenious and convenient rectifier connections. The writer can thoroughly recommend it where it is possible to obtain a couple of condensers of at least 4 mfds. apiece which will stand the voltage. The arrangement not only gives full-cycle rectification, but doubles the transformer voltage. Also for a given D.C. output only one-quarter of the number of cells used in the Fig. 3 arrangement is required, thus reducing the labour involved in constructing the rectifier as well as reducing the space taken up by the apparatus. Actually the D.C. output voltage on no load will be nearly twice the peak voltage of the transformer or nearly 2·8 times the R.M.S. voltage. On load this will fall to a little over twice the R.M.S. transformer voltage, depending upon the capacity of the condensers and the efficiency of the rectifier cells. If one requires, say, D.C. at 1,000 volts with this arrangement only about 10 cells are required and the transformer secondary need only give 500 volts. The arrangement in Fig. 5 should be particularly useful to men who have 220-volt A.C. mains as it will give them nearly 500 volts D.C. without the use of any transformer at all. The bigger the two condensers are the better. 6 mfds. each is quite a good value, but if larger condensers are available so much the better.

In the event of any reader being fortunate enough to have a 3-phase supply the con-

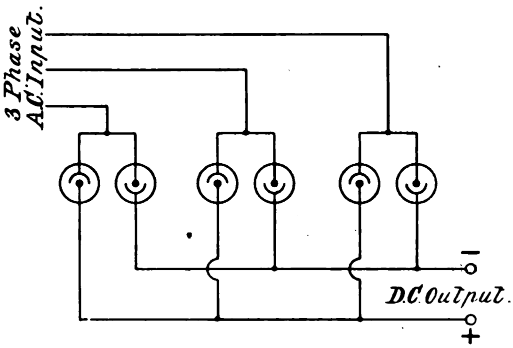


Fig. 6.—Scheme of connections for rectifying a 3-phase supply.

nections for a 3-phase rectifier is shown in Fig. 6. For simplicity each group is represented by one cell. The great advantage in a three-phase rectifier is that the D.C. output never falls to zero owing to the overlapping of the phases, so that without any smoothing arrangements at all there is always a steady continuous current component with only about 20 per cent. ripple. What ripple there is has a frequency of six times the supply frequency and is consequently very easily smoothed.

St. Dunstan's Broadcast.

In connection with the St. Dunstan's Carol League, a selection of Christmas Carols will be simultaneously broadcast from 2LO between 8.30 and 9 p.m. on December 23 by four gentlemen from St. Paul's Cathedral Choir. St. Dunstan's wish to ask every reader of EXPERIMENTAL WIRELESS to arrange listening-in parties amongst their friends, at which they will make a collection on behalf of the funds which they so badly need. We have little doubt that readers will be only too willing to comply with the request, and special collecting envelopes may be obtained from St. Dunstan's Headquarters, Regent's Park, London, N.W.1.

The Heterodyne Reception of Short Continuous Waves.

By Captain ST. CLAIR-FINLAY, B.Sc.E. (Laus.),

Late Chief Experimental Officer, Inter-Allied Research Commission, etc.

It appears that certain difficulty is experienced in the reception of weak short-wave signals. The following notes deal adequately with the subject, indicating how best to obtain efficient amplification without complicated circuits, and at the same time securing the minimum of interference.

In view of the forthcoming Transatlantic Tests, for which it now behoves us seriously to consider the preparation of our stations, a few notes upon the subject of suitable receiving arrangements may serve as a "refresher," and may not be inopportune.

The essentials of a receiver suitable for such a purpose may be summed up briefly as follows :—

(1) High sensitivity ;
(2) Ease of searching and tuning ;
(3) Self-silence ; and
(4) Non-interference.

Selectivity being a matter of course, as will be shown, whilst the fourth will speedily become obvious when two or more stations in a given area commence searching for given signals with energised aerials.

In order to design and effectively operate such a receiver the principles and considerations underlying the beat reception of C.W. signals must be appreciated, and it is here proposed, firstly, to discuss these relative to the special object in view, and, secondly, to describe certain forms of circuit which fulfil in considerable degree the necessary requirements.

It is known, firstly, that this system of reception is based upon the fact that when waves of different frequencies are allowed to interact, a third or "beat" frequency results which will be equal to the difference between the originating frequencies and must be lower than either, thus :—

$$f_\beta = f' - f'' \text{ or } f'' - f'$$

where f' = frequency of incoming or received oscillations,
f'' = frequency of local or heterodyning oscillations,
f_β = frequency of resultant or beat oscillations,

so that, although the originating frequencies may themselves be far above the limits of audibility, a resultant beat of any desired audible frequency may be produced according to the difference given to the former.

It is also known that such resultant beats must be greater in amplitude than the lesser of the originating oscillations, and will, in fact, be equal to the sum of the latter, since—

$$I\beta = (I'' + I') - (I'' - I') = 2I',$$

where I' = amplitude of incoming oscillations,
I'' = amplitude of local oscillations,
$I\beta$ = amplitude of resultant beats,

so that an amplification of the original signals amounting to $\frac{2}{1}$ results from the heterodyne effect quite independently of the amplifying action of the valve or other magnifier, and this ratio will hold good so long as the local oscillations are not inferior in amplitude to the incoming oscillations.

If, however, the latter are allowed to exceed the former a somewhat different state of affairs results, with very far-reaching effects. The production of beats, of course, remains unaltered, and the resultant amplification also remains unaltered, except in the important respect that, whereas in the former case it was the incoming oscillations that were amplified, it will now be the *local* oscillations that will be amplified, thus :—

$$I\beta = (I' + I'') - (I' - I'') = 2I'',$$

with the result that the incoming signals may not now be amplified at all, but may, on the contrary, actually be limited by the heterodyne action, as would occur were they of more than twice the amplitude.

The consequence of this being manifestly a loss in amplification of the desired signals, the importance of making the local oscillations strong enough will be evident.

Neither is this by any means all. Let us reconsider the first case, where

$$I\beta = (I'' + I') - (I'' - I') = 2I'.$$

Now, under these conditions the *selectivity* of the arrangement will be at a maximum, since $I\beta$ will depend entirely upon I' and not upon I'', so that the heterodyne amplification will be greatest under conditions of resonance (because I' will then be at its greatest), as will naturally apply to *desired* signals, and will fall off greatly as signals become detuned, as will apply to undesired signals unless these be of exactly the same frequency.

But now, if I'' be inferior to I', as in the second case, then the reverse condition

$$I\beta = (I' + I'') - (I' - I'') = 2I''$$

obtains, which means that $I\beta$ is now entirely dependant upon I'' and not at all upon I', so that variations in I'—whether of desired or undesired signals—produce no effect upon resultant signal strength, and undesired signals, although mistuned and therefore relatively weak, will consequently be heard as strongly as the desired signals so long as their amplitude be not less than that of I'', selectivity which is normally so valuable a characteristic of heterodyne reception being thus to a great extent lost. (Actually, this selectivity will be at a maximum when $I''=I'$, since under these conditions the resultant amplitude of undesired signals—however great their initial amplitude—will be limited by I'' and cannot exceed $2I''$, which will only be the same as that of the desired signals, so that these will usually remain readably selectable to within a small fraction of a metre—on short waves—by separation of the respective beat-notes—this being of considerable importance when interference is experienced, for example, from high-power or local stations operating or producing harmonics at or near the same wave-length—whereas if I'' exceed I' these may greatly exceed and completely jam the desired signals, it being thus sometimes of advantage to limit I'' to I'.)

But this is not the only consideration. It will have been noted from the foregoing that the amplification directly due to heterodyne action reaches a maximum when I' and I'' are equal and cannot be increased by increase of I'' beyond this point. Actually, however, a secondary but important effect of the local oscillations is to increase the efficiency of the detector by polarisation, so that an additional amplification effect independent of the actual heterodyne amplification and due mainly to improved rectification, is obtained, which increases (within limits) with the amplitude of I'', so that, in practice, *best result will usually be obtained when I'' is materially in excess of I', and is variable, which should, therefore, be provided for in the design of our receiver,* whether this be of the separate or auto-heterodyne type.

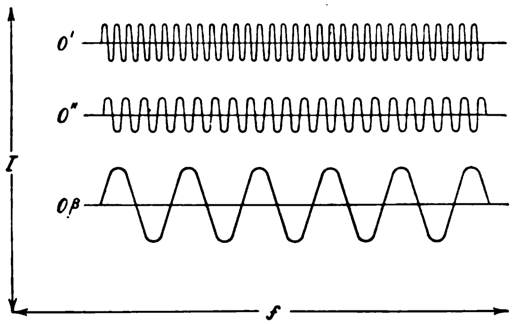


Fig. 1.—Illustrating the inter-action of two oscillations of equal amplitude and different frequency.

The relative merits of these will be discussed later, the next point to be touched upon being that of the actual sensitivity of the receiver itself to weak signals.

This—given that the aerial system, etc., has been made as efficient as possible—will depend mainly upon :—

(*a*) The circuital resistance ;
(*b*) The inter-electrode and circuital capacities ;
(*c*) The static inertia of the circuits ; and
(*d*) The sensitivity of the detector as such to feeble impulses.

(*a*) and (*b*) have already been discussed and their vital importance emphasised by the writer elsewhere in these pages (Vol. I, No. 1), and may, therefore, now be dismissed with the bare statement that *the resistance and inter-electrode capacity of valve circuits, particularly H.F. valve circuits, should be as small as possible.*

What may be termed the " static inertia " of circuits is a rather different—though closely allied—matter, which, considering its extreme importance where actual sensitivity is concerned, is usually insufficiently

considered. It should be appreciated that, whilst the current required by the grid to operate a valve is very small, and is commonly dismissed as "negligible," it is, in reality, by no means negligible when considered in relation to that available for its operation, *e.g.*, the currents due to the incoming signals, which are also minute. Thus, since P.D. is always proportional to charge for a given capacitance and inversely proportional to capacitance for a given charge, it follows that the smaller the capacitance of a circuit the greater the potentials set up therein by given currents, so that, valves being potential-operated devices, the inference is obvious that ***all valve circuits, and in particular grid circuits, should have as small a capacity as possible if sensitivity to weak signals is desired.*** Since the valve electrodes themselves, as well as external parts of the circuit—such as wiring, terminals, condensers, etc.—will manifestly enter into this matter of capacity, it follows that not only should the latter be kept as small as possible consistent with efficiency in their respective functions, but that the electrodes of valves intended to deal with weak signals—such, for instance, as H.F. valves—should also be small; and this, of course, applies especially to the first stage in a receiver, where a special high-frequency valve should always be used.

Now comes the all-important question of detector efficiency, upon which the successful reception of weak signals above all depends.

It being essential in this case that the system adopted be specifically suitable to the purpose intended, and not merely for general use, crystal detectors, owing to their comparative unreliability, can be ruled out and some form of valve detector regarded as essential; and amongst these it will be observed that no form of anode rectification will be suitable, since the characteristics of such are sensitivity to strong and relative insensitivity to weak signals, which is the reverse of what we here require; so that some form of grid rectification is indicated. This may be either of the grid current or cumulative variety, the latter, being somewhat the more sensitive to very feeble impulses, being the more suitable; and either of these, moreover, permit of the detector being utilised as the local oscillator in an autodyne circuit without loss of efficiency.

Our receiver should, therefore, employ leaky-grid-condenser rectification, and a valve specially designed for this purpose should preferably be used.

The next item of importance is amplification, *i.e.*, valve amplification as distinct from heterodyne amplification, which we have already discussed; and the first effect of this—assuming it to be on the radio-frequency side—will naturally be to increase the amplitude of the incoming oscillations so that stronger beats may be produced by the heterodyne action.

Now, since signals received from distances of 3,000 miles may be expected to be attenuated out of all comparison with the local oscillations produced by even the smallest valve, and since it is known that the rectified or telephone current output of a detector is proportional to the *square* of the impulses applied to it, it will be evident that *pre-heterodyne amplification of the signals will be of very great advantage in enabling reasonably strong beats to be produced for rectification, and may, in this case, be regarded as essential.*

A further advantage accompanying the use of H.F. stages is the fact that it enables a non-radiating receiver—even of the autodyne type—to be readily designed.

Since, however, radio-frequency valve circuits are somewhat tricky and liable to cause trouble if over multiplied, H.F. amplification has certain limits imposed by the need for practicability in a receiver and should not be overdone, and the condition to be aimed at is maximum amplification efficiency per valve, so that the number of stages necessary to produce a given result may be as few as possible—which, of course, also holds good from the standpoint of economy.

Since, moreover, this condition may be fulfilled by efficiency of circuital arrangements only up to a certain point (*vide* "practicability" below), it must be fulfilled as far as possible by the valves themselves—*i.e., the amplification factor of valves used for radio-frequency amplification should be high, and their characteristics made as steep as possible* by suitable values of plate voltage and filament temperature.

This will, in the present case, apply also to audio-frequency stages, since many such will be undesirable owing to their tendency to noisiness; in fact, in the interests of self-

silence of the receiver, which is here so important a matter, it is recommended that *not more than one L.F. stage, and preferably none at all, be used.*

Now comes the essential factor of *practicability, i.e.*, ease of searching tuning, etc., and we are faced with the necessity of reconciling this with efficiency as far as possible, since we cannot afford to lose either to any great extent.

Fortunately, both efficiency and selectivity are inherently greater in heterodyne than in telephonic reception, so that less difficulty exists in arranging a practical receiver which shall at the same time be satisfactory in these respects.

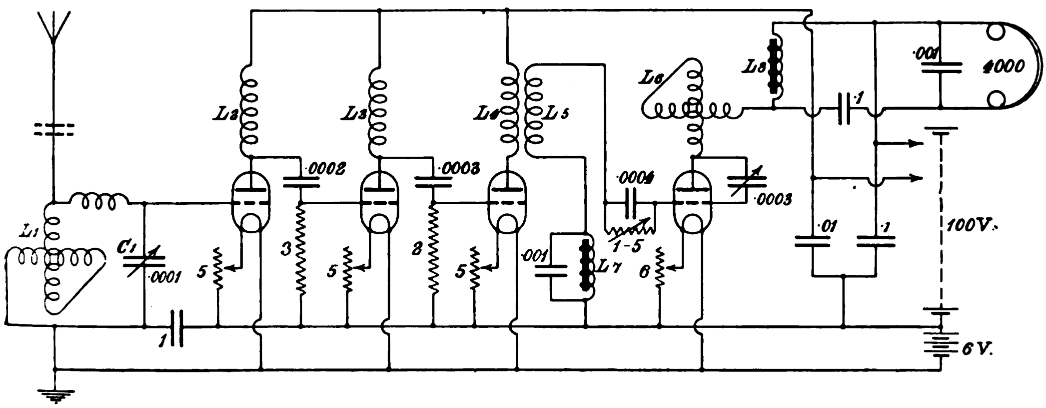


Fig. 2.—An "Interdyne" reaction circuit or four-stage autodyne receiver.

This is due to the absence of "spreading" of the carrier due to modulation, to the high degree of regeneration present in the circuits under working conditions, to the polarisation of the detector by the local oscillations, to the heterodyne amplification effect, and to the natural increase in selectivity due to the heterodyne action, which latter is so great as to make almost any heterodyne receiver inherently selective in such degree that, for short-wave work at all events, no special consideration need be given the matter so far as interference due to undesired signals is concerned. That due to atmospherics and to arc "hash" is a different matter, and will be discussed in due course.

We thus see that it is not in the matter of selectivity, but in the reconciliation of efficiency with practicability that the difficulty chiefly lies.

The former admittedly demands fully-tuned circuits throughout the radio-frequency side of a receiver, for example, but since the latter puts this out of the question where more than one—or at most two—H.F. stages are concerned, we must endeavour to find the best possible compromise.

Since the tendency to instability increases with each stage and becomes disproportionately greater with each *tuned* stage, and inasmuch as the complexity of tuning increases as the square of the number of tuned circuits employed, it will be evident that the latter must have a very strict limit, so that *a receiver intended for reception of intermittent signals of indeterminate frequency should have as few tuned circuits as may be consistent with reasonable efficiency, and experience shows the maximum number generally permissible in practice to be three.*

Now, since two—*viz.*, the aerial and the heterodyning circuits — will in any case be a *sine qua non*, this will leave only one more available irrespective of the number of H.F. stages adopted, so that, if more than one stage be used, these will have to be untuned, *i.e.*, semi-aperiodic.

In practice, however, it is found that even three tuned circuits in a receiver make anything like rapid and reliable searching and tuning difficult, and cause the chances of missing signals to be considerable—in fact, no less than 9 to 1, which odds are rather long, and may have a serious effect upon the percentage and total number of stations logged in a given period.

This rather cramps us, as it leaves only two tuned circuits with which to produce

"efficiency"; but, since it is in practice possible to dispense with one such circuit out of three without serious loss of efficiency, and as the advantage in practicability gained by doing so will usually outweigh any such loss, it is suggested that *a limit of two tuned circuits may be adopted with advantage in receivers to be used in the Transatlantic Tests*—"tuned" circuits, of course, here meaning such as actually require variation in searching and readjustment for any change of wave-length.

The desirability of avoiding interference with other stations that may be working being manifest, it is also suggested that *a non-radiating arrangement be in all cases adopted—e.g.*, that reaction be not applied directly to the aerial circuit, either open or closed; that at least one H.F. valve stage be interposed between the aerial circuit and that to which the heterodyne is applied; and that signals be in no circumstances heterodyned in the aerial circuit itself or in any circuit directly coupled thereto.

Three types of receiver designed in accordance with the various considerations enumerated are now shown.

Fig. 2 shows a four-stage autodyne circuit in which the amplified signals are heterodyned by a detector-oscillator V_4, preceded by three H.F. stages. Here the audio beats are produced in the grid circuit of V4, three valves thus separating the aerial and oscillation circuits and energisation of the aerial being completely avoided. It will be observed that two tuned circuits only—L1-C1 and L6—are used, *inclusive* of the oscillator, C1 being merely a vernier for fine tuning, and C2 a static coupler. (The iron-core choke L7 is merely an audio-frequency rejector of the beat-oscillations, so that these may be effectively built up in the grid circuit of V4 and passed on for rectification in their entirety—a point usually neglected, but which will be found repeated in each of the receivers here illustrated. It is shown shunted by a small fixed condenser so as to constitute an acceptor of the higher frequencies and not interfere with the action of L5 as a high-frequency circuit. It has no effect when the receiver is used for telephony, spark, etc., other than slightly to increase the efficiency of the detector as an audio-frequency amplifier. Both it and the impedance choke L8 should have a resistance of at least 4,000 *w*.)

It has already been stated by the writer elsewhere in these pages (Vol. I, No. 1) that an autodyne receiver may be used for *short* wave work as efficiently as a separate heterodyne, and, as this may not be the generally accepted view, the reasons for it are here given.

The first is that, whilst it is manifest that a certain amount of de-tuning of one or other of the circuits concerned will be necessary for the production of an audio beat-note, this de-tuning in the case of short waves will only be very small, and, moreover, if the receiver be scientifically designed for the purpose, need not occur in the actual receiving circuit at all, so that the incoming signals need by no means be inefficiently tuned. Thus in Fig. 2 the de-tuning, or heterodyne frequency, may be and should be in L6 only, and not in L1, so that, L6 being post-rectificational, and its tuning without very material effect upon preceding circuits, the loss of signal strength will be negligible.

The second is that, since the received signals will pass through *all* the valves, and each will, therefore, be directly operative as an amplifier (which is not the case in a separate heterodyne), any small loss in strength due to de-tuning of L6 will be more than compensated for by the extra amplification due to V4 itself.

The third reason is that searching and tuning are generally easier in an autodyne than in a separate heterodyne, as the receiving and heterodyne frequencies are varied to a certain extent simultaneously, so that adjustment of the beat-note is less critical and signals are less likely to be missed. This is an actual advantage of the autodyne, and it is suggested that, for wave-lengths below, say, 200 metres, the latter is actually the superior arrangement, although on medium-short waves there is probably little to choose between them.

Fig. 3 shows a five-stage receiver with separate heterodyne, the amplified signals being here heterodyned in the anode circuit of V3, preceded by three H.F. stages, and followed by the detector, two tuned circuits only being still used. The local oscillator may here be simply a heterodyne wavemeter.

The advantage of this type of receiver is that the required beat-note is produced by variation of the local oscillations at L5-V5 only and not in the actual receiver, the signals thus not losing strength through de-tuning of the receiver itself. Moreover, the majority of headphone instruments are designed to have a natural period in the neighbourhood of 1,000, which corresponds to that of most acute audibility, and such a frequency may here readily be given to the beat-note without other considerations becoming involved, whereas in the case of an autodyne receiver the amount of de-tuning of the circuits necessary to produce such a note may appreciably affect signal strength, so that, in practice, a lower valve is not itself directly useful as an amplifier, and is, therefore, partly wasted.

Fig. 4 shows an entirely different and considerably superior arrangement, which has been specially designed for the purpose in view, and operates on the Supersonic principle.

Space will not permit of any enlargement upon the subject of super-heterodyne receivers here, but the circuit itself is given owing to its special value in this case. Suffice it to say that it operates in the main upon exactly the same principles and is subject to the same considerations as have already been discussed, with the difference that the beat-note produced, instead of being given an audible frequency, is given a *supersonic*

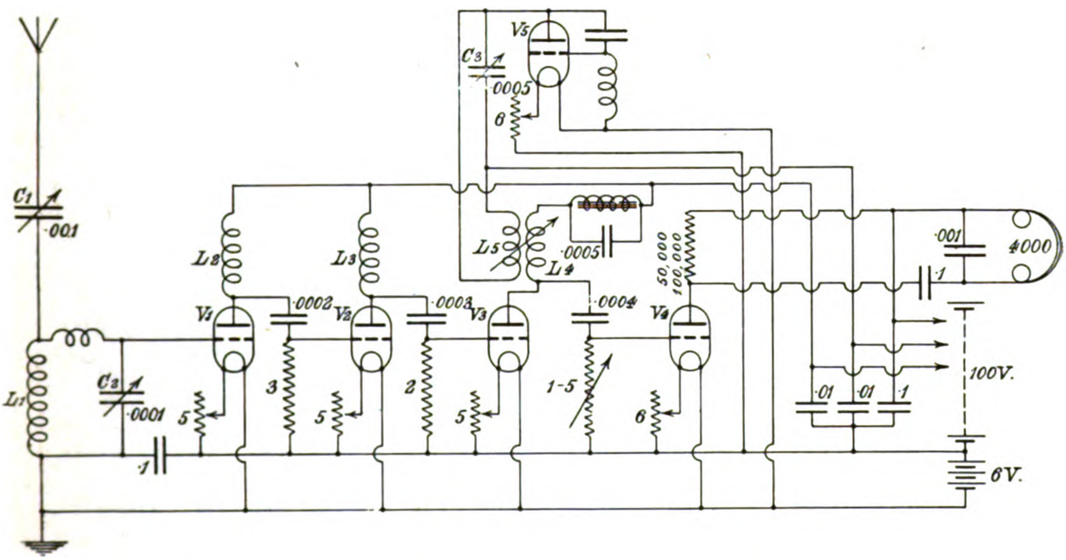


Fig. 3.—An "Exterdyne" reaction circuit or receiver with seperate heterodyne.

note of the order of 500-600 usually has to be adopted.

In the case of a separate heterodyne receiver the note will, of course, be adjustable by variation of the heterodyne frequency (at L5) *only*, as variation of the receiver tuning cannot alter the frequency of the incoming signals themselves, or, therefore, the beat-note.

The disadvantages of this type of circuit are, on the other hand, the criticalness of adjustment of the heterodyne frequency on short waves, and the fact that the oscillating frequency, *i.e.*, one above the limits of audibility and corresponding to a fairly low *radio* frequency, and is subsequently treated as such.

Thus, in Fig. 4, the incoming signals are amplified at their original frequency by V1 and V2 in the usual way, and are then heterodyned by the local oscillator V3 to produce a beat-frequency, also as usual, except that the frequency chosen in this case will be of the order of, say, 100,000 instead of 1,000, corresponding to a wave-length of about 3,000 metres instead of

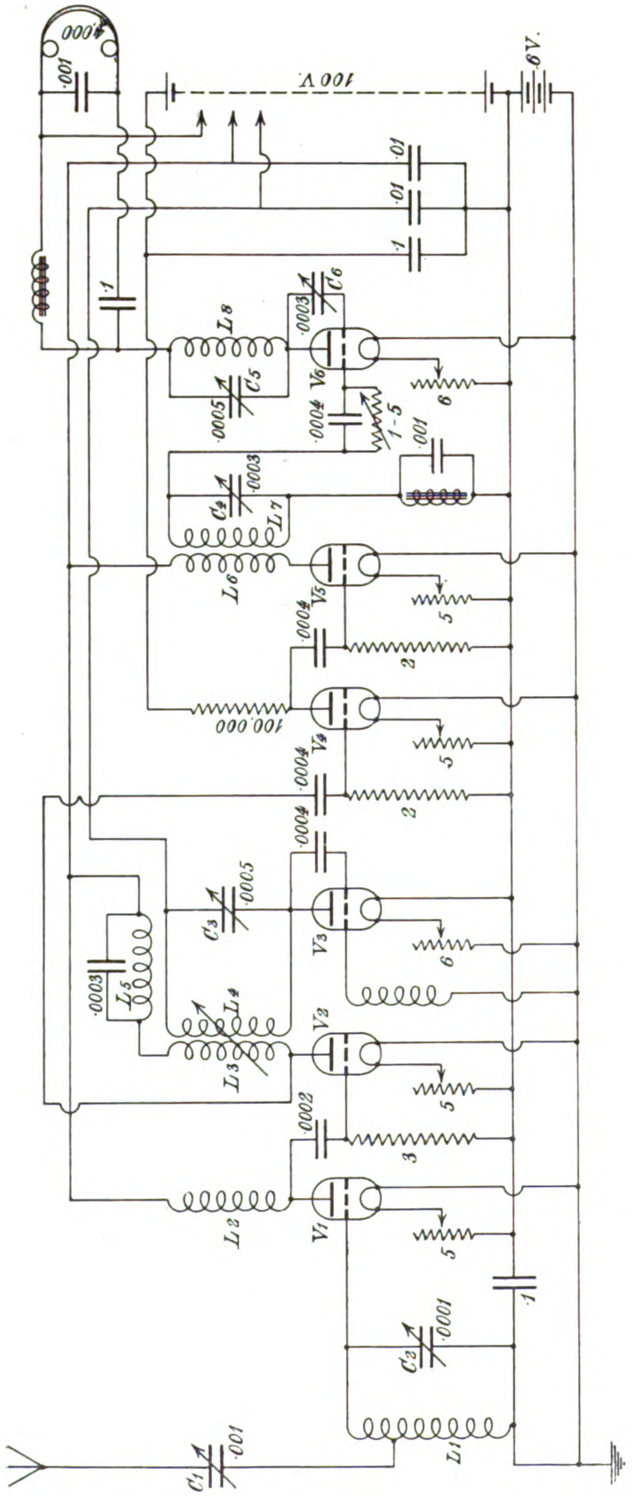


Fig. 4.—A "Superdyne" receiver which operates on the supersonic principle. The incoming signals are amplified by the valves V1 and V2, and are heterodyned by the local oscillator V3 to form a beat note of about 100,000, corresponding to a wave-length of 3,000 metres. The beat note frequency is amplified by the valves V4 and V5 being subsequently rectified by V6. The valve V6 also acts as a second heterodyne, which is adjusted to produce an audible beat note.

an audible note. This is conveyed to V4 and V5, where, being still a radio-frequency, it is amplified as such before rectification by V6, which also acts as a second oscillator to re-heterodyne it for the production of a final *audible* note in quite the usual way.

V3 is an ordinary separate heterodyne, which is, in this case, desirable as the de-tuning necessary to produce a beat-frequency of anything like 100,000 would cause considerable inefficiency in an autodyne arrangement. It may in this case, as it will form an essential and permanent part of the receiver, be "built in" as shown in the diagram. Similarly, though only an audio-frequency is required at the final stage V6, considerable de-tuning will be necessary to produce it when the originating frequencies are as low as 100,000, so that, although a self-heterodyne arrangement will here answer quite well, and is actually adopted in Fig. 3 with a view to suiting the receiver to permanent general use, a separate oscillator is really to be preferred.

L6 in the anode circuit of V5 is semi-aperiodic at the first beat-frequency—say, 3,000 or 4,000 metres—and constitutes an acceptor of the no longer required original frequencies and of any interfering currents—such as arc-hash, spark, and, to some extent, static—which may accompany them, and which usually force us to work at four ack-emma, these being thus filtered out to a great extent. It may be tuned if desired, but this is by no means necessary.

They are further suppressed by the use of resistance coupling between V4 and V5, which, whilst quite efficient for amplification of relatively low frequencies such as that of our beat, is very inefficient at the high frequencies in which the "mush" demon lives, so that any of these that may escape the filters L6 and L7 remain unamplified and comparatively pure signals at the new frequency to which they have now been converted are passed on to the last valve V6, which is the oscillator-detector, the grid circuit L7 of which is tuned to the new frequency and the anode L8-C5 to a slightly different one, such as to produce an audible rectified note in the telephones (except, of course, in the reception of telephony, when V6 will be used as a detector only and not as an oscillator).

It would appear from the diagram that a considerable number of tuned circuits are involved, and that the arrangement would be rather awkward to operate, but this is by no means the case. It must be appreciated that, whatever the original wavelengths received, the beat-frequency to which they are converted will always be what we choose to make it, so that a suitable beat-frequency may be adopted once for all and used for all receptions, the long-wave part of our receiver being set thereto in the first instance and *permanently left so*. Likewise, when a suitable audio note has once been found there will be no need to alter it again, and this may be permanently set, too. In fact, the variable capacity C4, which is merely for the purpose of setting the long-wave circuit in the first instance, may be dispensed with altogether if the inductances L6-L7 are carefully calibrated. Thus in practice the number of tuned circuits actually used in searching and tuning-in is still *two only*—L1-C1 and L4-C3—inclusive of the oscillators, notwithstanding that adequate amplification of the fundamental—an important matter too commonly neglected—is duly provided. The rejector L5 in the anode circuit of V2 is unusual, and its purpose is to improve the circuit in its function of *long* wave oscillator, whilst it is shown shunted by a small condenser to improve it as an acceptor of the higher frequencies so as not to impair the circuit as a *short* wave oscillator. It should be resonant at the lower frequency—say 3,000–4,000 metres—and L6-L7 made the same.

The coupling between L3 and L4, by means of which the local oscillations are introduced into the receiver, is shown variable in the figure, but in practice once a suitable setting has been found any adjustment in the strength of the oscillations that may subsequently be necessary can be obtained within sufficient limits by variation of the anode voltage to V3 or by adjustment of its filament temperature, or both, without any disturbance of the tuning of any of the circuits, the same applying to V6 and its static coupler C6 (which is made variable to allow of the oscillation here being stopped when the receiver is used for telephony, spark, etc.), and, indeed, to the heterodyne couplings in each of the figures; and it should here be pointed out that, whilst one form of oscillation circuit is shown in

these diagrams, any other appropriate form may, of course, be used according to choice.

The outstanding advantages of a super-heterodyne receiver are :—

(1) Great sensitivity and amplification, particularly of C.W. signals, due, in the latter case, to the *double* heterodyning.

(2) Extreme selectivity from the same cause, without increased criticalness of tuning.

(3) Ability to eliminate arc-hash, etc.—which is amongst the most serious difficulties in the way of short-wave long-distance reception—to a considerable extent.

(4) Ability to use a long-wave amplifier, relatively insusceptible to stray capacities, for the greater part of the receiver, with consequent reduction of body-capacity and other disturbing effects, resulting in far less instability and criticalness of adjustment and a more easily operated receiver for short waves.

The use of such a receiver, whilst perhaps a little more troublesome to set up and become accustomed to in the first instance, is likely to make a material difference to the success of receptions and is strongly to be recommended.

With regard to details, all inductances shown in the diagrams, particularly those forming the anode coils of valves, which are intended to be semi-aperiodic, should be wound to have the least possible self-capacity. Whilst any efficient form of tuner, such as shown in the preceding figures for example, may of course be used for the aerial circuit, variometer tuning will be found very practical and efficient and may safely be used with either of the receivers shown.

The aerial itself should preferably be an inverted L or T of the single or twin wire type, as high and long as possible, and may be used with either direct earth or counterpoise as lower capacity. Too many wires in the antenna tend to increase the interference due to mush, static, etc., and are inadvisable.

"R" valves may be used quite well throughout either of the receivers at the frequencies concerned, but those recommended are V.24 or ORA B. for the H.F. stages, and R.4B. for rectification. A "Q" valve will give particularly good amplification at V4 in Fig. 3 if a high-tension voltage of about 150 is used with it.

The H.T. battery should be of large capacity, whilst the filament accumulator should have a capacity of at least 60 amp.-hours (actual), unless of course dull-emitter valves are used, as is sound practice owing not only to current economy, but to the very desirable silence in operation of valves of this type. In this case suitable valves will be D.E.V. for the H.F. stages, and B.5 for rectification, the filament voltages of these coinciding very closely.

It will be noticed in each of the circuits shown that the last valve—*e.g.*, the detector—is made to function as an L.F. amplifier also, partly by the action of the iron-core choke in its grid circuit, and partly by the use of a static transformer, operating on the impedance or resistance-capacity principle, in its plate circuit, with high-resistance telephones, and this arrangement will be found very efficient. Low-resistance 'phones with ordinary transformer may, of course, be used if desired, and instruments of the adjustable-reed type may in either case be used with advantage.

Suitable constants are given in the figures, and, it being appreciated that few will want to build special receivers for the short period of the tests which may subsequently be of little use to them, an effort has been made to suggest circuits which shall also be of all-round use and permanent value to the experimenter afterwards.

The Institution of Electrical Engineers.

Mr. E. H. Shaughnessy, O.B.E., Chairman of the Wireless Section of the Institution of Electrical Engineers, delivered his Inaugural Address at the Institution Building, London, on November 7. He commenced by pointing out that the meetings of the Wireless Section are open to all members of the Institution; they are not, as seems to have been the impression, limited to members of the Section only. The address was of an interesting character; it reviewed the inception and development of broadcasting, mentioned the difficulties which had occurred in the United States, and predicted the eventual establishment of a sound national order of broadcasting in this country. Mr. Shaughnessy referred to the broadcasting of music as a wireless triumph.

Radio 2UV A.R.R.A.

By W. E. F. CORSHAM.

Amateur transmission stations usually show a marked dissimilarity in circuits, systems, and apparatus employed. This is due no doubt to the fact that many experimenters build their sets as a result of their own investigations. In order that experimenters may become acquainted with the work of others, details of stations embodying novel methods and circuits would be welcomed in these pages.

EXPERIMENTAL station 2UV, better known as "Two Uncle Vic," the station's 'phone call, is located in the valley at the bottom of Harlesden Gardens, London, N.W.10, and came into action at the beginning of 1920, the twin aerial being hoisted almost immediately after my demobilisation from the R.E.S.S. The first difficulty consisted of getting gear together, and, due to this trouble, a crystal set was the first set in use. I wonder if the broadcasting people know what a wonderful amount of interest can be got out of a crystal set? Most of the Mediterranean stations were copied off this set, and it was in use for quite a long period, giving entire satisfaction, and on some nights some remarkable performances.

Fig. 1.—Showing the general appearance of 2UV.

When the first amateur transmitters began to get into operation on 1,000 metres did anyone ever hear such a large amount of Q.R.M. that immediately began to spring up on that wave-length; BYK and other Navy sparks using about 2 to 5 kw. seemed to work most of the day and nearly all night, and the "Sorry, O.M., Q.R.M.!" got so frequent that it was obvious that a new wave-length would have to be found, especially as Croydon was occasionally being Q.R.M. by a slight miscalculation of wave-length, and PCGG had commenced music tests. The non-transmitting amateurs began to voice their disapproval of the heterodyning effect of carrier waves on this station, so that the poor transmitting amateur, already well bound up by restrictions, began to look for some other wave to release his experiments on, and the first stragglers began to appear on 360 metres, where, in course of time, new emigrants from 1,000 appeared every evening, until in time 360 began to get as bad as 1,000 metres for congestion. Then the Cross Channel commercial sets began to get busy, and shipping

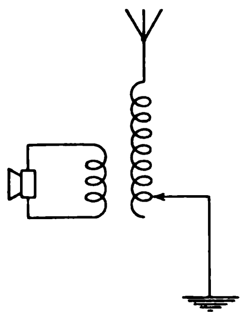


Fig. 2.—The simple modulation system consists of an absorption coil coupled to the aerial circuit.

to increase their use of the 300-metre wave. D.F. stations on 400 to 440 also got busy, and down we went again to 200. Finally the Post Office authorities sanctioned the use

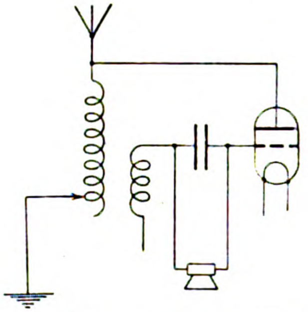


Fig. 3.—Here the microphone replaces the normal grid leak.

of 200 and 440 metres and the 1,000-metre wave-length was closed for amateur work.

The first transmitter at 2UV consisted of a tonic train set, radiating ·06 on 1,000 metres, 0·1 on 360 metres, and 0·13 on 200 metres. This was, I believe, the first tonic train set of its kind to be used in London after the war, the feed consisting of 4 volts on a ¼″ spark coil, taking about 2 amps. in primary coil, and supplying heavens knows how many volts on the plate, but very few milliamps., hence the low radiation. Very successful results were obtained with this set, quite good distances being worked, an example being the tests worked with 2JZ of Huntly, Aberdeenshire, in February, 1922, when he received my signals and replied to me on a set whose input was less than 50 watts. I got his speech very well on a three-valve L.F. set. That's 500 miles on a set radiating 0·1 amps., whose actual wattage must have been in the region of 2 to 3 watts output, and good clear speech on 50 watts.

The set used can be seen in Fig. 1. A small power 'phone set, also radiating 0·1, came into being at this time, with about 120 volts on plate ; good speech at 20 to 30 miles was obtained on this input, and on some very special tests arranged with 2OD and 2SX, they received my speech Q.R.Z., but clearly when my input consisted of the six-volt

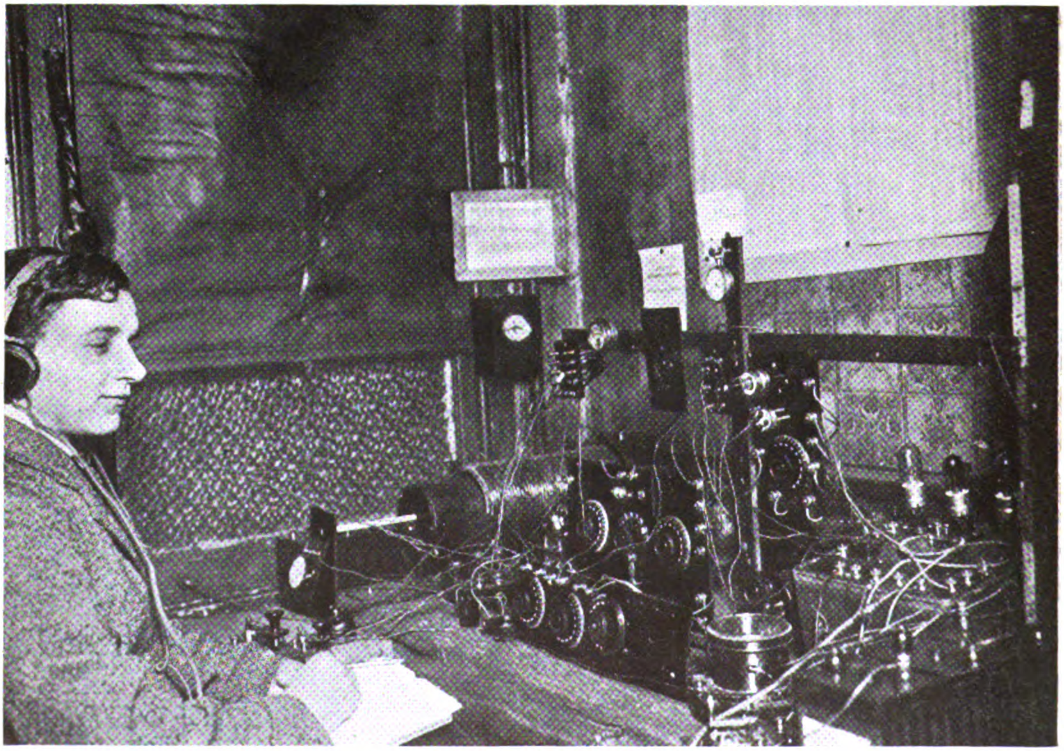


Fig. 4.—The apparatus employed by 2UV during the last Transatlantic Tests.

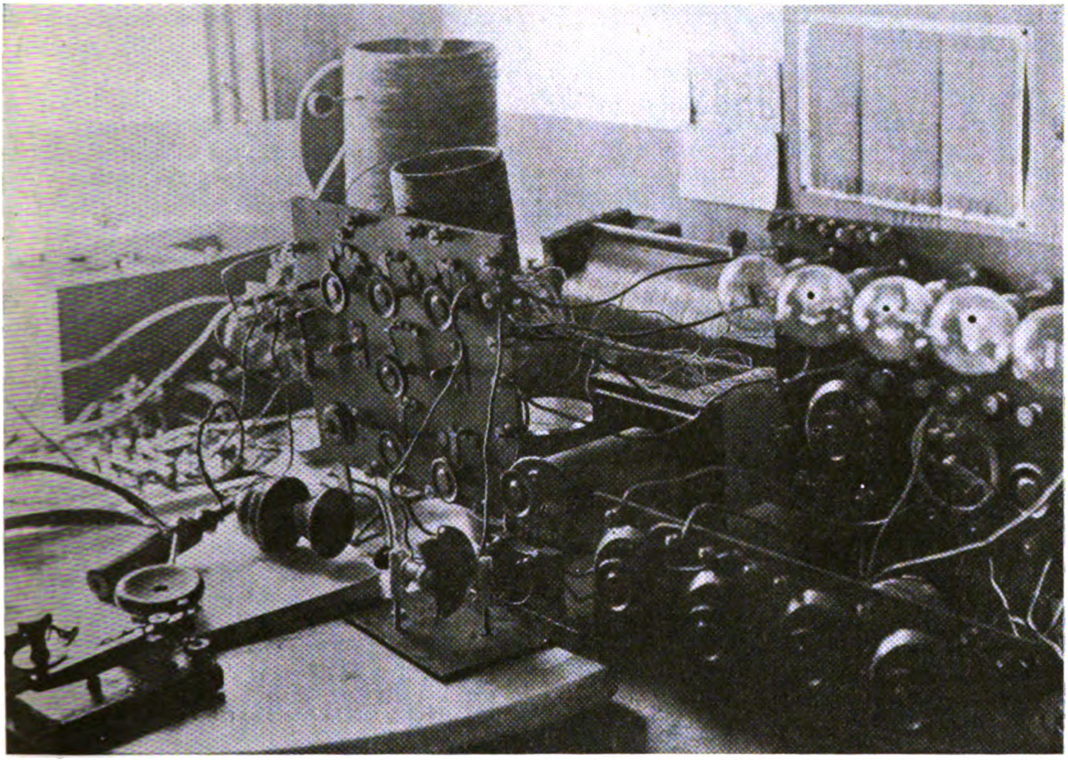


Fig. 5.—A near view of the apparatus now in use at 2UV.

accumulator supplying the valve filaments, and a four-volt dry cell from the H.T., very much the worse for wear; in other words, a doubtful ten volts. How did I modulate it? Perfectly simple—a coil coupled to the aerial circuit on the earth side will do this very well, but a better and much easier system is as in Fig. 3, where the microphone, shunted by a condenser, takes the place of the grid leak. This system works excellently on radiations up to 0·2, but heavy saturation begins to set in here, and ordinary grid control is far more reliable then, but wonderfully clear results are obtainable on these systems at low inputs, and a good deal of unnecessary trouble and fuss can be saved. So much for the transmitter.

The receiver at 2UV is possibly one of the most efficient of its kind in London. The first record put up was the first reception of the American amateurs in Great Britain, when 2UV successfully logged 1AFV of Salem, Mass., on a three-valve set (L.F.), a most astounding piece of work, considering that it was the first time the receiver had

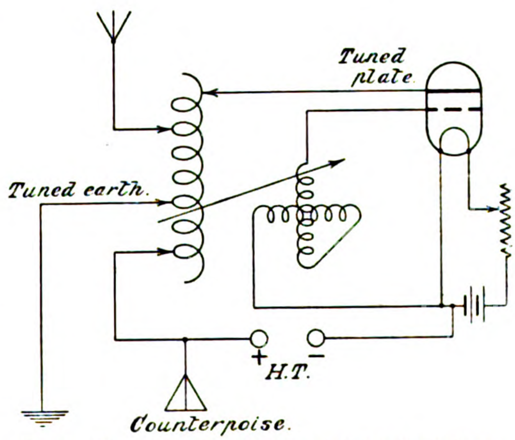


Fig. 6.—Illustrating the circuit employed for transmission.

got down to 200 metres, and that the first three hours it was at work saw the code word

YLPMF safely in the log book. Since then numerous experiments have taken place, too long to elaborate upon in this article, but the first French tests were arranged on October 31 with 8LBC, and very good Q.S.A. results obtained. Before the 1922 transatlantics were commenced a rather interesting incident, worthy of mention here, occurred, and possibly the first of its kind in this country. On November 26, 1922, at 11.59 p.m., when testing out the set I was going to use for the coming tests, and working with 2OD, of Gerrard's Cross, to my annoyance a C.W. station came dead on top of him, making reception exceedingly hard. I couldn't get one tuned out without getting the other, and accordingly I took steps to listen to the Q.R.M. man with a view to asking him to change his wave-length, when, to my surprise, he turned out to be American amateur 2AWF, working 1XM. Needless to say, I did not call him, but that reception certainly augured well for the success of the coming Transatlantic, and, despite the awful Q.R.M. from Northolt GKB, I logged nearly 200 stations from periods 3 a.m. to 6 a.m., GKB making reception hopeless up to 3 a.m., I am so near him. I first heard WJZ's howl in February, 1922, and 0NX I logged on December 10, 1922, together with 0NY. I took part in the transmission period tests from this side, and had some good reports from various places on the Continent, tonic train being used. No doubt 2KF, 2OM, and 2SH remember those early morning chats that passed away the hours of waiting for the period, the station at 2UV in use then being pictured in Fig. 4.

The present station will be seen in Fig. 5, and consists of a tonic train set capable of radiating 1 to 2 amps.; a C.W. and 'phone set capable of radiating 0·7, and a five-valve receiver one to five valves at will. The usual number in use being two. Most of the U.S.A. broadcasters have been logged on this, together with a good number of American amateurs.

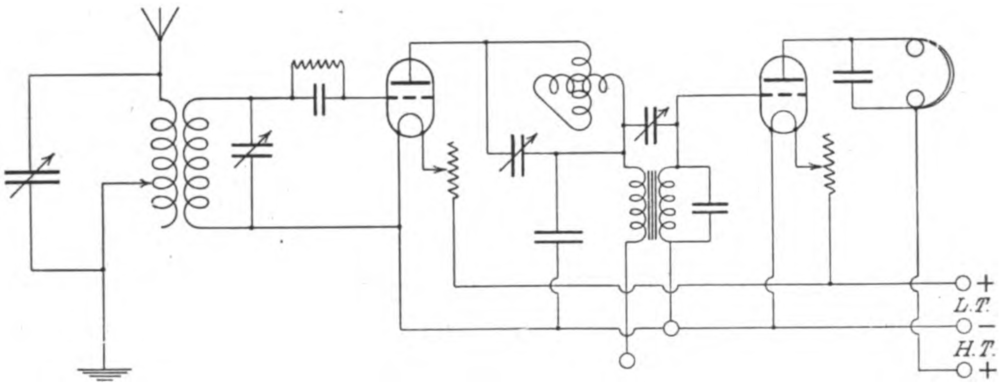


Fig. 7.—The receiver employs a single valve regenerative circuit with tuned plate coil, followed by a special note magnifier.

The circuit of the transmitter is shown in Fig. 6, and that of the receiver in Fig. 7. I always use L.F. because it is my practical experience that much better results are obtainable on distance work if great care is exercised to clear distortion for speech, and it is quite possible to get rid of that bugbear to the low-frequency worker. The only good word I have for H.F., and I have at times used it fairly extensively, is for its better selectivity, and I use it occasionally when GKB is Q.R.M., but a good tuned circuit is just as good.

This concludes a rough outline of 2UV, and the work accomplished since its inauguration. A 1-kw. license has been granted to the station by the P.M.G., and if all goes well, I hope for good DX work with the U.S. amateurs in the near future, together with my brother amateurs of the A.R.R.A. "Best 73's C.Q.!"

The Month's "DX."

Recorded by HUGH N. RYAN (5BV).

The increasing efficiency of amateur transmitters and receivers is resulting in the creation of many new long-distance records which are undoubtedly worthy of mention. It is proposed to record month by month work in this direction, and the Editor will be pleased to receive details for inclusion in these pages.

THE outstanding feature of the past month has, of course, been the extraordinary spell of bad conditions, lasting about five weeks, and including the whole of October, during which reception of American amateurs was practically impossible. The conditions on the early morning of September 23 were perfect, and Americans were coming in nearly as fast as they could be logged. It was a few days after this that last month's notes were written. Apparently I was crowing about the splendid conditions a little too soon, as I heard not a single American between that date and November 10, neither have I heard a report of any other listener doing so. 2JF, 2ZS, 2KF and other well-known men all report to the same effect.

The Transatlantic aspect of these notes was in imminent danger of disappearing this month when quite suddenly normal conditions returned. They may or may not last, but at the time of writing all is well. Now for the actual results obtained. Reports from the North are not yet to hand, but certainly London has been getting some excellent logs.

On the morning of October 11 5NN logged twelve Americans on one valve. 2WY received the very fine total of twenty-three on the same morning, using three valves. About twelve Americans were received on one valve by 2AAH (British, not American !), who has one of our latest series of call-signs, but is nevertheless an "old-timer" in DX work. I only kept a short watch that night and received ten Americans on one valve.

I heard 2JF and 5KO calling 1CMP several times, so it may be assumed that they were also on the war-path.

The two strongest Americans were 1CMP and 2BY, both of whom produced very loud signals indeed. An interesting item was an A.R.R.L. broadcast message from 1FD. This was rather badly jammed in London, but parts were quite readable, including a report of a cable just received from England in connection with Transatlantic work. The message was signed "Schnell," the A.R.R.L. traffic manager. That practically concludes the American news, since the bad weather spell only broke a few days before writing.

Canadian 1AR has written asking for the co-operation of British amateurs in Transatlantic work to show our American "Radio-Cousins" how DX really can be conducted. He is using transmitting apparatus of British manufacture, and works with an aerial current of 7½ amps. He would appreciate reports of reception in this country, having been received here a record number of times in August and September.

A curious feature of the spell of bad conditions was that it only seemed seriously to affect Transatlantic work. European DX has not been seriously hindered by it. The Dutch stations have been coming in very well, but nothing of great interest has occurred in connection with any of them except PCII of Leiden, who reports having effected two-way working with 7ACM on the morning of Sunday, October 4, between 3 and 4 a.m., Amsterdam time. The whole of the working was overheard and confirmed by oMX of Amsterdam.

The Dutch "Radio-Expres" states that PCII was using 100 watts, and radiating 3 ampères, using a Mullard valve with 1,500–2,000 volts on the plate. The working remains to be confirmed, but if it turns out to be authentic it is a very fine piece of work, as the seventh district is the one most remote from Europe, and 7ACM is at Cambridge, in Washington State, right over on the Northern Pacific coast of America ! We will leave our congratulations until it is confirmed.

The only other notable feature of Dutch work this month is the sudden and considerable increase in the strength of oDV.

The French stations are now awaking from their summer sleep, and have been very much in evidence during the last month. I suggested in last month's notes that 8AQ's silence was due to the non-arrival of his new alternator. It appears that the reverse is the case. The alternator turned up, full of beans, and 8AQ is now having his valves repaired! 8BF, of Orleans, has just installed a new transmitter, using 25 cycles A.C. The signals from this set are extremely strong, and the note is exactly like the once-familiar note of 8AB. 8BF tells me that the power of this set is one kilowatt, and that during the Transatlantic tests he is going to use it alternately with his old 100-watt pure C.W. set. In spite of the power of the 25-cycle set, I think I would put my money on the pure C.W.

There are now several more British stations "on the air" with their potential Transatlantic transmitters. 5NN has been suffering from valve trouble, but is now working again. 2SH is again using big power, under a special licence for 100 watts. He is putting about 4 amps. into the aerial. Several other stations have been granted these temporary licences for increased power during the Transatlantic season, and may soon be expected to establish some interesting records. An important point in connection with these licences is that, under their terms a British station calling an American should prefix the American call sign with the letter "n" and his own call sign with the letter "g," *e.g.*, "n 1CMP de g 2JF." This will help to avoid confusion between British call signs and their American duplicates. It is to be hoped that all British transmitters using sufficient power to render distant reception possible will, in future, use this prefix. It is much less clumsy than the present "British" or "Brit." prefixes.

In connection with the issuing of special licences for Transatlantic work, it is interesting to note that the Dutch authorities have sanctioned the erection of a station for this purpose, the licence allowing the station to operate until May, 1924.

The station is to use C.W., power 500 watts, and wave-length 200 metres. It is to be situated at Delft, and its call sign is PA9.

It will be remembered that last month I suggested that the fault of the non-reception of our signals in America did not, perhaps, lie entirely with the receivers on the other side, as is rather commonly supposed by our men. I think that my view is confirmed by the results obtained by several American amateurs in *working* with the Macmillan Expedition Station WNP. The Macmillan ship is at present frozen in the Arctic at a nearer point to England than to an average point in the States, but yet he has carried out two-way working with several American amateurs, while he has never yet been received in England, neither has he received any British signals. That, I think, should dispel the idea that American amateurs cannot receive. This should give us more hope of getting over so long as we send out good stuff, and it should also encourage us to try to receive WNP. I know that many of our stations are trying to do so, and it is difficult to explain their lack of success.

With regard to the well-known Americans of last year upon whose absence this year I commented in the last notes, the list still holds good with the exception of 1BDI, who has now been logged this year by 5NN (November 11).

Apart from the chronicling of DX, I should like this month to put forward a suggestion for the better reporting of signal strength in DX and other work. The present "R" code of signal strengths has become useless, firstly because it has far too many different degrees of audibility, and secondly because everybody applies a different meaning to it. Nobody can really say what is the difference, for instance, between R5 and R6, nor is that difference of sufficient importance to be worth worrying about.

I suggest a new code, which should be called by a different letter to distinguish it from the old "R" code, which should have only four degrees of audibility, and which should take into account the receiver used. Let us call it the "A" code, then "A21" would mean strength 2 on one valve.

The figures for strength would be—

1—just readable (with difficulty).
2—comfortably readable, but not very strong.
3—good strong signals (the best strength for good consistent work).
4—very strong.

The second figure should indicate the

number of valves used for reception. Even this code is far from perfect, but it is an improvement on the practically meaningless "R" code. If you like the code you can use it without much fear of the other man not understanding, as I think that this paper is read by nearly all transmitting men.

Just before going to press the log from the North has come to hand. 2JF has received eighteen Americans so far this month. His transmitter has also been heard in Christiania (indoor aerial and two valves) and Toulouse (two valves). 8CWR has reported receiving 2JF, but the time is not yet confirmed, though it appears to check O.K.

2PC, 2GW and 2KW are all rebuilding their stations for the tests, and may soon be expected "on the air."

The Trend of Invention.

We summarise below the more important wireless inventions which have been disclosed during the month, special reference being made to those of immediate interest to the experimenter.

Elimination of Interference.

A great deal of experimental work has been done, and a great many patents have been taken out, on the subject of the elimination of interference. Still, however, much remains to be done in this direction. British Patent No. 205,117 (of German origin) shows a method of attacking this problem in a somewhat novel way. In order to increase the selectivity of resonant circuits the inductance thereof is made very large and the capacity very small. In order to produce coils of very large inductance and very low self-capacity these are wound with fine wire and may have iron cores and be of multi-layer form. The losses so occasioned are neutralised by using a retroactively-coupled triode. A wireless receiving circuit is shown in Fig. 1, in which a separate triode (R_1) is used to neutralise the aerial losses and the closed circuit (S_3, C_3) of the receiving set is inductively coupled to the aerial tuning coil (S_1). S_5 is the coupling coil of a separate heterodyne. The telephone may be inserted in the anode circuits of either R_1 or R_2, thus making possible the use of either a direct-coupled or loose-coupled receiver. It does not appear that the arrangement described would overcome the difficulty of heavy atmospherics setting the aerial into oscillation at its own natural frequency. However, the arrangement produces a very feebly-damped aerial circuit for a loose-coupled tuner and thereby enhances the benefit of loose coupling. A possible improvement might be found in tuning the reaction coil S, for example.

Relay Arrangements.

A certain amount of experimental work has been done on the lines of causing an incoming signal to set a local valve in oscillation at a frequency independent of the

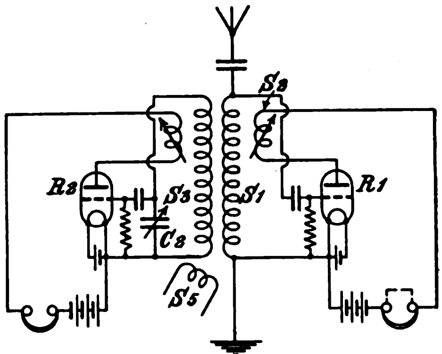


Fig. 1.

incoming signal. This, as will be remembered, is the principal of the Turner valve relay. British Patent No. 183,130 (of German origin) deals with arrangements of this type. Fig. 2 shows the simplest arrangement. Owing to the rectifying action of the two diodes 3 the negative charge on the grid of the triode 6 is reduced in proportion to the strength of the oscillations in the closed circuit 2. This effects the raising of the conductivity of the filament-anode

space of the triode 6. The anode circuit of this triode is in series with the anode circuit of a second triode 7, which is retroactively coupled. Thus the triode 7 will oscillate, when the potential on the grid of 6 becomes sufficiently positive, at the frequency to which it is tuned, which would generally

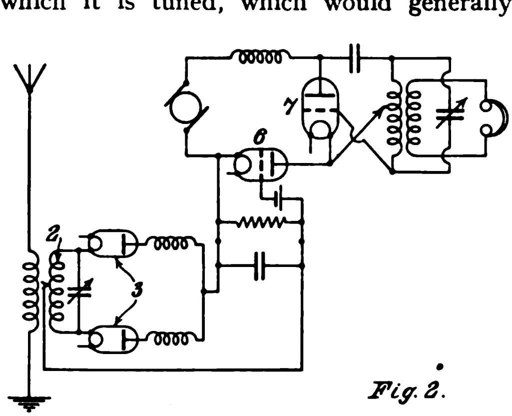


Fig. 2.

be an audible frequency. Other arrangements are shown in the patent specification using triodes only, and circuits may be arranged for the relaying of received signals at a different frequency.

Another relay device is described in British Patent No. 186,305 (of French origin). This arrangement depends upon the effect of ultra-violet light upon metals in a low-pressure atmosphere. In the arrangement particularly described the beam from an arc lamp is focussed upon one electrode in a two-electrode tube, and the beam is controlled by perforated slip. The current

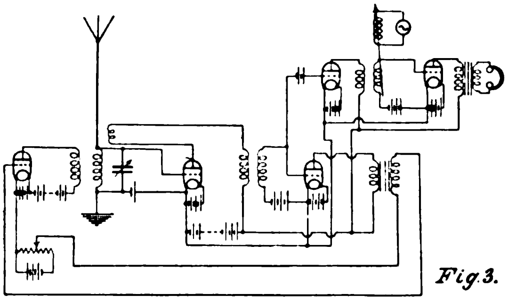


Fig. 3.

in the tube circuit is said to be proportional to the intensity of light falling upon the electrode. The beam may be controlled by a mirror or mirrors, or, for example, by a pair of grids, of which one is connected to a sound-collecting diaphragm. It is possible that in this way a very sensitive microphone arrangement might be made, since a grid of fine wires, to cover slits in a screen, may be made very light indeed.

Controlling Decrement of Circuits.

A most interesting principle and means for carrying this into effect is shown in British Patent No. 204,482 (E. Y. Robinson, British). According to this patent the decrement of receiving circuits is caused to decrease with a weak and to increase with a strong signal, and remain constant when the signal is constant or zero. Preferably, the incoming signal itself effects these changes, and in such a manner that the change of decrement is proportional to the rate of change of signal strength. This can be effected in several ways, all dependent upon changing the normal grid potential of a triode in proportion to the rate of change of the signal strength. An extra transformer is included in the anode circuit of the detector triode, and its secondary winding is connected in

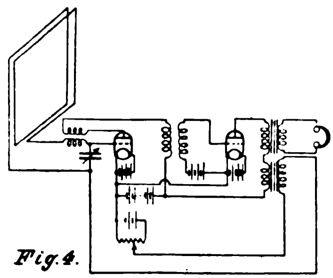


Fig. 4.

series with the grid and filament of another triode. An inductance in the anode circuit of this latter triode is coupled to the aerial inductance so that some energy is absorbed therefrom, the amount of which will depend upon the anode circuit conductivity, and hence grid potential of this triode. Reaction into the aerial circuit is used in this case. A circuit arrangement employing this principle is shown in Fig. 3. A similar effect may be produced by changing the amount of regeneration due to a retroactively-coupled tube by varying the grid potential of this tube. A suitable arrangement for this purpose is illustrated in Fig. 4. It is said that by this method the modulation of telephony can be improved and circuits of lower decrement than usual can be used. It appears that some precautions are necessary

to make the arrangement work well; for example, it would seem necessary to design the H.F. transformer in Fig. 4 so that substantially no audio-frequency energy transference could take place between its windings. Incidentally, there is a similarity between this arrangement and some fairly common reflex arrangements. Are some of the wonderful results claimed for certain reflex circuits due to the unbeknownst employment of the principle disclosed in this patent?

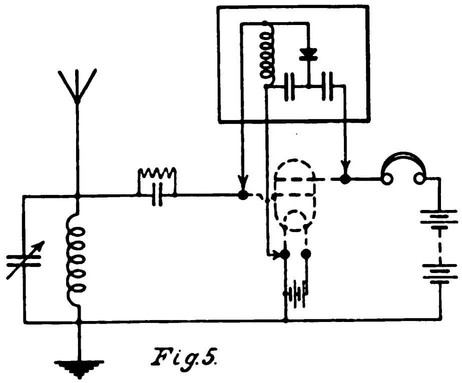


Fig. 5.

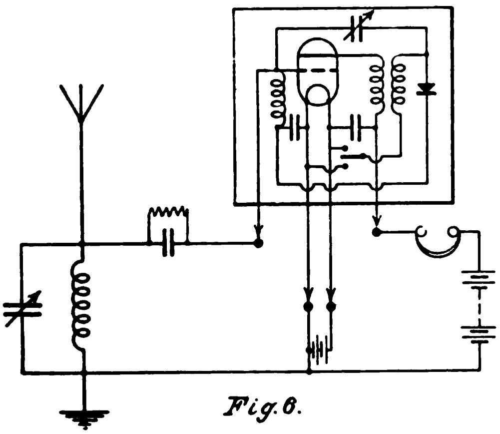


Fig. 6.

Crystal Detectors.

It is sometimes useful to be able rapidly to change from a single-valve circuit to a circuit employing a crystal or similar detector. British Patent No. 205,148 (P. G. A. Helmuth, British) describes two arrangements for plugging in to the socket of a detector valve, the first being for crystal detector only, and the second being for a crystal and triode reflex arrangement. Diagrams of these arrangements are shown in Figs. 5 and 6. The circuits used are somewhat unusual, but appear simple, but the construction of the high-frequency transformer in Fig. 6 might require some care.

Reflex Circuits.

Much attention has recently been devoted to reflex circuits, particularly those employing a crystal detector. In reflex circuits it has been usual to impress the rectified signal upon the grid of the first H.F. triode, and thereafter carry out audio-frequency amplification throughout the series of triodes in the same order as they are used for radio-frequency amplification. This method has the disadvantage that one triode carries both weak radio-frequency currents and weak audio-frequency currents, while another

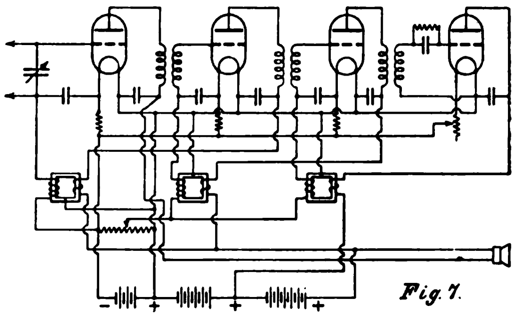


Fig. 7.

carries strong currents at both frequencies, and is therefore liable the more easily to become saturated. British Patent Application No. 204,301 (of American origin) sets forth a method of overcoming this trouble by carrying out audio-frequency amplification throughout a series of triodes in an order different from that in which radio-frequency amplification is performed, preferably in the reverse order. The diagram of connections is shown in Fig. 7. Particular care must be taken in designing and making the radio-frequency transformers for this arrangement, as it is essential that practically no energy at audio-frequency should pass between their windings. Amplifiers working on this system have found some popularity in America, and are said to be much more stable than the ordinary reflex amplifier. In that country these circuits are called "Inverse duplex circuits."

Duplex Telephony.

Many experimenters have during the last year been working hard at duplex telephony,

and in this branch of work there is great scope for experiment. British Patent Application No. 190,699 (of German origin) describes a method of effecting duplex telephony which appears very simple. The

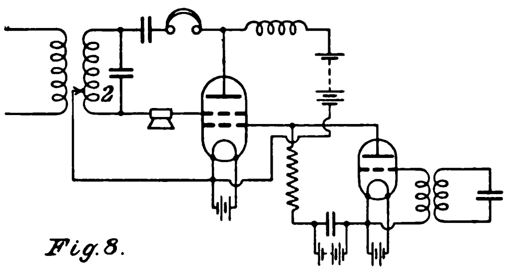


Fig. 8.

arrangement is shown in Fig. 8. The oscillating valve has four electrodes, a kathode, anode and two grids. The grid nearer the anode is used in conjunction with the anode and kathode to function as a triode and form the oscillator. The oscillatory circuit is of a fairly usual form, except that in the anode and grid leads respectively a telephone and microphone are connected. The extra grid adjacent to the filament is connected to the junction of a resistance and the anode of another triode. The grid of this latter triode has potentials of the requisite frequency impressed upon it by suitable means, shown as a transformer with the primary shunted by a condenser. The anode current in the oscillator is controlled by the potential of the extra grid. When the anode current is large the set functions as a transmitter, and when the anode current is small the set functions as a receiver on the same wavelength. The specification states that ordinary triodes may be used, but does not detail how this may be done. It is possible that the magnetic control, described by Mr. Andrewes in the November issue of Experimental Wireless, could be used to replace the extra grid shown by this specification.

Recent Wireless Publications.

Figures after the title of each publication indicate Volume and Number of Publication containing the article. Where only one number is given, this indicates the serial number of the publication. The abbreviations used in this bibliography will be found in the previous issues of "Experimental Wireless."

I.—TRANSMISSION.

An Improved Method of Modulation in Radio Telephony.—Charles A. Culver (*Proc. I.R.E.*, 2, 5).

Uber Parallelschaltung von Röhrensendern.—A. Semm (*Jahrb. d. drahtl. Telegr.*, 22, 3).

An Interesting Control Device for Radio-telephony.—Alan L. M. Douglas (*W. World*, 221).

Side-Band Telephony.—E. H. Robinson (*Exp. W.*, 1, 2).

The Principles of Choke Control.—L. E. Owen, (*Exp. W.*, 1, 2).

Radio Antenna Design.—Frank Conrad (*W. Age*, 11, 1).

Sur les conditions de rendement des lampes-valves génératrices ayant une caractéristique d'arc chantant et sur la définition de leur puissance.—André Blondel (*R. Elec.*, 4, 14).

A Real Short Wave Transmitter.—Brown, Darne and Basim (*Q.S.T.*, 7, 3).

I.C.W. Without Mechanical Motion.—Howard M. Williams (*Q.S.T.*, 7, 3).

II.—RECEPTION.

Der Empfang von Hochfrequenzschwingungen mit Niederfrequenzmodulation. — G. Joos and J. Zenneck (*Jahrb. d. drahtl. Telegr.*, 22, 3).

Messungen der Empfangsintersität der atmosphärischen Ionisation und anderer meteorologischer Elemente während Sonnenfinsternis an 8 April, 1921.—B. Iliin (*Jahrb. d. drahtl. Telegr.*, 22, 3).

Zur Frage nach den Ursachen der Schwankungen in de Empfangsintensität.—B. Iliin (*Jahrb. d. drahtl. Telegr.*, 22, 3).

The Automatic Reception of Wireless Signals.—E. R. Batten (*W. World*, 219).

"Blind Spots" and "Fading of Signals."—S. R. Chapman, B.Sc. (*W. World*, 221).

A New Dual Circuit.—James Strachan, F.Inst.P. (*W. World*, 221).

The Supersonic Heterodyne Receiver.—W. S. Barrell (*W. World*, 222).

New Types of Valves.—(*W. World*, 222).

Valve Receivers on D.C. Mains.—Alexander Gayes, M.J.Inst.E. (*Exp. W.*, 1, 2).

Dull Emitter Valves.—(*Exp. W.*, 1, 2).

Les accrochages dans les amplificateurs.—André Delvigne (*R. Elec.*, 4, 15).

Resonance Wave Coils.—(*Q.S.T.*, 7, 1).

III.—MEASUREMENT AND CALIBRATION.

The Construction and Manipulation of Wavemeters.—Leonard J. Sayce, B.Sc. (*Exp. W.*, 1, 2).

FACTORS OF WAVEMETER DESIGN AND OPERATION.—L. R. Felder (*W. Age*, 11, 1).

A METHOD OF MEASURING VERY SHORT RADIO WAVE-LENGTHS AND THEIR USE IN FREQUENCY STANDARDI'ATION.—Francis W. Dunmore and Francis H. Engel (*Proc. I.R.E.*, 2, 5).

IV.—THEORY AND CALCULATIONS.

VACUUM TUBES AS POWER OSCILLATORS.—D. C. Prince (*Proc. I.R.E.*, 2, 5).

THE EFFICIENCY OF THREE-ELECTRODE TUBES USED FOR THE PRODUCTION OF CONTINUOUS WAVES IN RADIO TELEGRAPHY; THAT IS, THE CONVERSION OF DIRECT INTO ALTERNATING CURRENT.—Marius Latour and H. Chireix (*Proc. I.R.E.*, 2, 5).

LONGEUR D'ONDE OPTIMUM.—Léon Bouthillon (*R. Elec.*, 4, 14).

V.—GENERAL.

OBSERVATIONS ON LAFAYETTE AND NAUEN STATIONS IN WASHINGTON, MARCH 1, 1922, TO FEBRUARY 28, 1923.—L. W. Austin (*Proc. I.R.E.*, 2, 5).

RADIO FREQUENCY TESTS ON ANTENNA INSULATORS.—W. W. Brown (*Proc. I.R.E.*, 2, 5).

DIGESTS OF UNITED STATES PATENTS RELATING TO RADIO TELEGRAPHY AND TELEPHONY; ISSUED JUNE 26, 1923—AUGUST 21, 1923.—John B. Brady (*Proc. I.R.E.*, 2, 5).

UNTERSUCHUNG EINES ELEKTRONRELAIS AUF GRUND ELEKTROSTATISCHER ABLENKUNG DES ELEKTRONENBUNDELS DURCH EIN QUERFELD.—A. Gebbert (*Jahrb. d. drahtl. Telegr.*, 22, 3).

L'INFLUENCE DE TRACES DE GAZ DANS LES LAMPES À TROIS ELECTRODES.—(*L'Onde Electrique* No. 14, 1923.)

A NOVEL METHOD OF RECTIFICATION.—F. L. Hogg (*W. World*, 219).

DISTORTION IN RADIO-TELEPHONY.—H. A. Thomas, M.Sc. (*W. World*, 222).

MAGNETICALLY-CONTROLLED VALVES.—H. Andrewes B.Sc., A.C.G.I., D.I.C. (*Exp. W.*, 1, 2).

AMATEUR RADIO WORK IN HOLLAND.—J. Westerhoud (*Exp. W.*, 1, 2).

A PRIMARY CELL H.T. BATTERY.—N. K. Jackson (*Exp. W.*, 1, 2).

IONIZATION IN VACUUM TUBES.—W. A. Dickson (*W. Age*, 11, 1).

NOTES ON INSULATION PHENOMENA.—A. Reisner (*W. Age*, 11, 1).

SINGLE-LAYER INDUCTANCE COILS SUITABLE FOR RADIO FREQUENCY STANDARDS.—(*Mod. W.*, 2, 2.)

SOME CAUSES OF POOR RECEPTION.—R. W. Hallows, M.A. (*Mod. W.*, 2, 2).

THE CONSTRUCTION OF A NOVEL FOLDING FRAME AERIAL. (*Mod. W.*, 2, 2).

ANTICIPATIONS SUR LA TRANSMISSION DE L'ENERGIE À DISTANCE.—Léon Bouthillon (*R. Elec.*, 4, 14).

SUR LES ORIGINES DE LA T.S.F.—Prof. A. Turpain (*R. Elec.*, 4, 15).

LA T.S.F. EN YOUGOSLAVIE.—R. Belmère (*R. Elec.*, 4, 15).

LE SERVICE D'ÉCOUTE PENDANT LA GUERRE.—Gen. Cartier (*R. Elec.*, 4, 16).

A PROPOS DES ORIGINES DE LA T.S.F.—(*R. Elec.*, 4, 16.)

LA RADIOTÉLÉGRAPHIE EN TCHÉCOSLOVAQUIE.—R. Belmère (*R. Elec.*, 4, 16).

LE PHONOGRAPHE DE L'AVENIR.—E. Pepinster (*R. Elec.*, 4, 16).

TRANSATLANTIC RADIO TELEPHONY.—H. D. Arnold and Lloyd Espenschied (*Electn.*, 2,372).

THE PARIS RADIO CENTRE.—(*Electn.*, 2,373.)

ELECTRIC FILTERS. PART II.—F. S. Dettenbaugh (*Q.S.T.*, 7, 1).

FINAL REPORT ON THE FADING TESTS.—(*Q.S.T.*, 7, 1).

HARD RUBBER IN RADIO INSTRUMENTS.—(*Q.S.T.*, 7, 1).

A NEW RADIO SYSTEM.—Howard J. Tyzzer (*Q.S.T.*, 7, 3).

ELECTROSTATIC VOLTMETERS.—R. R. Ramsey (*Q.S.T.*, 7, 3).

Correspondence.

Variable Condensers.

To the Editor of EXPERIMENTAL WIRELESS

SIR,—As an experimenter in wireless telegraphy of long and pre-war standing, I am wishful to assist the present experimenter, and incidentally the broad-catcher, who intends constructing his own set, by pointing out to him a possible cause for disappointment in the results obtained when endeavouring to follow too literally the valuable instructions for constructing a set as given by the various undeniably expert writers who contribute articles to the several wireless journals.

I write with regard to the capacities of the condensers therein stated to be necessary, and the risk when purchasing many of the condensers now on the market, of being supplied with one of much less capacity than the value at which it is rated.

I have recently come up against a most glaring instance of the gross inaccuracy of one of the types, for although I possess a number of Mark III condensers, and others made up to various capacities, I was led to purchase a condenser purely because it possessed an extra Vernier plate built therein.

It was sold to me as a condenser of .0005 microfarad capacity, and I had no reason to doubt its approximate accuracy, as, so far as my memory serves me, it had about 31 closely-spaced plates.

Being found to be *mechanically* defective, it was returned to the dealer, and by him to the makers, and another make of condenser supplied in substitution, with an apology from the makers for the same being of less capacity, namely, .0003 micro-farads, as they were out of stock of .0005 condensers for the moment.

Upon their stock being replenished, the makers forwarded to the dealer several condensers, and then stated that the condenser sent as a substitute was of .0005 and not of .0003 capacity.

Upon it being measured, and its capacity calculated, it was found to be round about .0003 micro-farads, and therefore representations were made to the makers, who now reply that "*there*

is a standard number of plates usual in the trade for the various capacities" (apparently without regard to the diameter and thickness of the moving plates, and thickness of the spacing washers, that is, to the actual active air space between the plates).

Now, this cannot be a correct statement, as one cannot believe that trade firms would knowingly misrepresent the capacities of the condensers they sell. Moreover, a reference to the list of one of the most prominent makers of condensers shows that his .0005 micro-farads condenser has 29 plates, and a .0003 19 plates, whereas the so-called .0005 I purchased had 11 moving plates, equal to 23 plates all told, and the .0003's they sell have seven moving plates, equal to 15 plates in all, so that presumably, if there is a *standard number* of plates, the latter types do not comply with the standard.

Had the condenser been sold to me as having a certain number of plates, I could not have objected, excepting that the one sent in substitution had a much smaller number of plates.

I have also compared the said .0005 condenser, having 11 moving plates, with a cheap American condenser, containing 28 moving plates, with a much closer air space, and stated to be of .001 capacity, and this confirms my view that there can be no standard custom in the trade, as to the number of plates.

The point which affects the amateur is that he is advised that with a certain coil and a certain capacity of condenser he can cover, say, the broadcasting range of wave-lengths, and finds upon assembling his set that it falls short of this range, and wonders why.

Summing up for the guidance of the investigator, there can only be one correct method of calculating condenser capacities. One square inch of active surface, with an air space of $\frac{1}{1000}$ of an inch, gives a capacity of .0002246 micro-farads, and each moving plate of 2¼ in. diameter if faced on *each* side with a *fixed* plate (having a centre piece of ⅜ in. radius cut out for clearance, and having an air space of $\frac{1}{1000}$ of an inch) will give a capacity of approximately .0008 micro-farads, and in the case of a 2½ in. moving plate, .001 micro-farads.

If the spacing is $\frac{25}{1000}$ of an inch, then the capacity per *moving* plate will be one twenty-fifth of the above respectively, and if the plates are 23 S.W.G., and the spacing washers ⅛ in. thick, the capacity will be about one-fiftieth of the above.

Finally, it would be interesting to know the legal position of a dealer who knowingly sells an alleged .0005 micro-farad condenser (actually of about .0003 capacity) as a condenser having a capacity of .0005 micro-farads.

GEO. H. STRONG.

To the Editor of EXPERIMENTAL WIRELESS.

DEAR SIR,—With reference to the article entitled "Efficient Transmission," by Mr. F. L. Hogg, in the October issue, there appear to be certain points which, so far as my limited technical knowledge goes, do not fit in with each other, and as to which I would much appreciate an explanation—even if it only shows up my ignorance.

From particulars given, it appears that Mr. Hogg's aerial is 70 ft. above the counterpoise level at the lead-in end. The height of the other end is not stated, but I think it safe to assume that the average height is 50 ft., or say, 16 metres. Mr. Hogg further states that he has reduced the total resistance of his aerial system to 5 ohms, and on this basis shows how 1.26 amps can be obtained with an input of 10 watts to the valve at 80 per cent. efficiency.

What puzzles me is this: How does Mr. Hogg make his aerial system have a total resistance of 5 ohms when the radiator resistance alone works out at over 10 ohms (calculation attached).

If Mr. Hogg actually gets 1.26 amps. in his aerial on 10 watts at 80 per cent. efficiency, it is obvious that the total resistance of his aerial cannot be more than about 5 ohms, else he would have more than 10 watts in his aerial, which is ridiculous.

Awaiting your reply.—I remain, yours faithfully,

A. B. RICHARDSON (6FQ)

CALCULATION OF RADIATION RESISTANCE OF MR. F. L. HOGG'S AERIAL ON 200 METRES.

Formula $1580\left(\frac{H}{\lambda}\right)^2$

Where H = effective height of aerial.

λ = Wave-length.

See *Wireless World*, page 652, issue of 17-2-1923.

$$1580\left(\frac{16}{200}\right)^2$$

$$=10.112 \text{ ohms.}$$

To the Editor of EXPERIMENTAL WIRELESS.

DEAR SIR,—With reference to Mr. Richardson's remarks *re* my aerial, I can only say that I wish my aerial was 70 ft. above the counterpoise! I purposely split up this length into parts to emphasise the actual length of wire. The lead-in comes through the roof and across the room. The counterpoise lead goes back across the room a greater distance and across a short roof before dropping vertically on to counterpoise. Actually the aerial is 45 ft. above ground at lead-in, and 35 ft. at free end. Its effective height is only 28 ft., as the counterpoise is 12 ft. high. This figure gives a radiation resistance on 200 metres of 3.2 ohms true radiation resistance. Actually owing to R_g and R_d the total resistance is 5.8 ohms, and the aerial current is 1.20 amps. at 85 per cent. efficiency. I hope this clears up Mr. Richardson's difficulty.—Yours faithfully,

FREDERIC L. HOGG.

To the Editor of EXPERIMENTAL WIRELESS.

DEAR SIR,—There seems to be a prevailing impression that when D.C. mains have their positive lead earthed they can only be used for high tension by putting a condenser in series with the earth lead (which still leaves the aerial at high potential), or using loosely-coupled circuits. This, however, is not the case; all that is necessary is to connect the bottom end of the inductance to the H.T. positive instead of the L.T. negative. All the tuning instruments, as well as the 'phones, are now at earth potential. Of course, if the first valve is a high-frequency amplifier, the grid condenser and leak have to be specially introduced.—Yours faithfully,

W. LAWRENCE.

Some Impressions of the Wireless Exhibition.

That the second All-British Wireless Exhibition and Convention has been a gigantic success is no secret. Some idea of its popularity may be gathered when it is realised that at one time the queue of interested sightseers waiting to gain admission reacted a length of some three-quarters of a mile. We offer our heartiest congratulations to the organisers who paid attention even to the most minute details with such gratifying results.

It is only natural to imagine that an annual exhibition of this nature should reflect the advance and progress which the industry has made during the preceding year. If we adopt this attitude, then we must certainly express some disappointment. Taking the exhibits as a whole, we cannot honestly say that we found signs of any startling improvements or innovations. True, the manufacturer has had to devote the whole of his time to meeting the demand for broadcast receiving apparatus, and perhaps thereby he has been unable to give as much time to research as he would have liked. Nevertheless we were able to notice some really excellently designed receivers. The exhibition was essentially a " broadcast show," and it would be unnatural to imagine that the experimental side of amateur wireless work should predominate

Perhaps the most striking feature amongst modern developments was to be found in valve construction and loud-speaker design.

One could not glance even casually around the show without noticing the predominance of dull emitter valves, several new types making their first appearance. Amongst these were the Cossor " Wuncell," constructed on the lines of the familiar Cossor valve, and the small thoriated filament valve, such as the D.E.3, A.R.O.6, and B.4, which resemble the U.V.199 described in the November number of EXPERIMENTAL WIRELESS. Two other newcomers were the B.T.H. B.5, somewhat similar to the U.V. 202A and the Cossor dull emitter power amplifier. The construction of the latter is of interest, as it will be observed that the grid is very rigidly connected to the anode by means of a supporting glass lug. So far as power valves are concerned there is little to report, except, perhaps, the new Cossor low-impedance high-tension rectifier in which the drop is only of the order of some 30 volts. This should be of special interest to amateur transmitters. We were interested to note that the Mullard 50-watt valve is now capable of being re-filamented.

The Frenophone, a frictional loud speaker; the Burndept " Vase," and the " Crystavox," incorporating a microphone relay.

Progress in loud speakers has been in three directions. Better quality, better appearance and new principles have been the chief considerations. The well-known Amplion is now fitted with a wooden horn, a welded and pressed " throat," and an improved movement with a view to reducing resonance effects, resulting in an even more pleasing tone. In appearance the Burndept vase loud speaker is certainly the most novel. The Frenophone frictional loud speaker made its first appearance befoie the general public. A small Brown loud speaker, fitted with a microphone relay to

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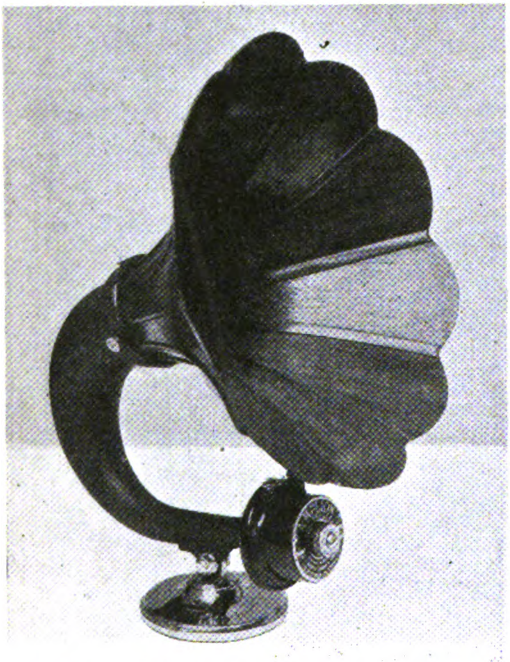
operate from a crystal set, proved an attractive exhibit. Other attempts to eliminate resonance were to be found in the T.M.C. "copper-lead-copper" horn and the Hart Collins' instrument designed on the lines of the human throat.

While dealing with the subject of distortion, one may mention several loud-speaker filters such as the Beldam, Peronet and Fuller tone compensator. These components, of course, are connected to the output circuit, and are adjusted to give the desired speech quality.

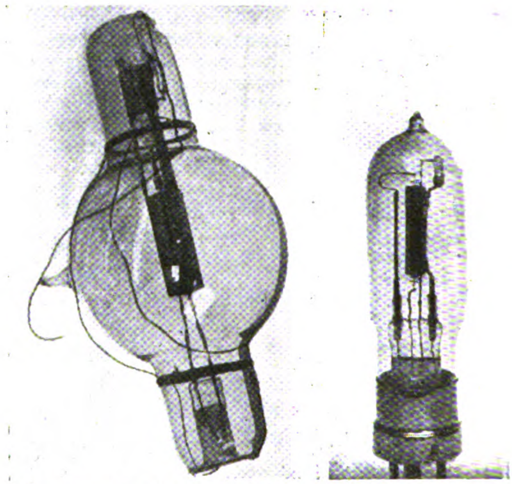
So far as batteries are concerned, the most interesting exhibit was the Darimont primary cell, which is too complicated to deal with here. It



In the new Amplion the metal is welded and pressed and a wooden horn is used to prevent resonance.

may be said, however, that it has a remarkable performance, and we hope to discuss it at some later date. The Alkeum cell, shown by Radio Acoustics, Ltd., is a form of Edison battery having a voltage suitable for many of the dull emitter valves.

Coils of all types were very prolific, and one was apt to wonder what material advantages some of the specimens possessed. Perhaps the most interesting coil development was the "Cosmos Strip," consisting of several spaced wires fixed to a long roll of insulating paper. A multi-layer coil is wound with a strip and the two ends are subsequently cross-connected. Of course there are many possible permutations and combinations of connections, and many applications suggested themselves. It would seem that the strip could be of great use in the manufacture of high-frequency transformers. We were interested to note a new skeleton gimbal-mounted Igranic duolateral coil and coil-holder incorporating several novel features. Rough coupling is obtained in the ordinary way, final adjustment being secured by means of a long frictionally-geared anti-capacity handle. Another Igranic innovation is a type of high-frequency transformer composed of two concentrically-mounted duolateral rolls. While mentioning the

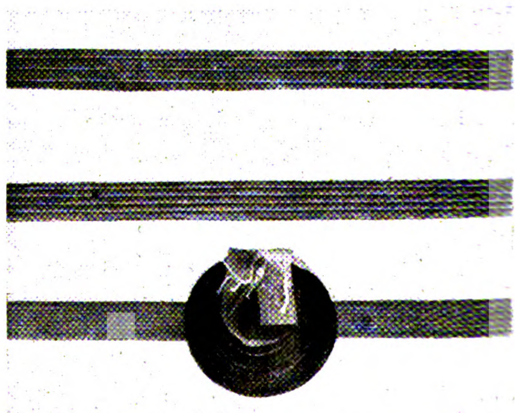


A new Cossor low-impedance rectifier and a dull-emitter power amplifier.

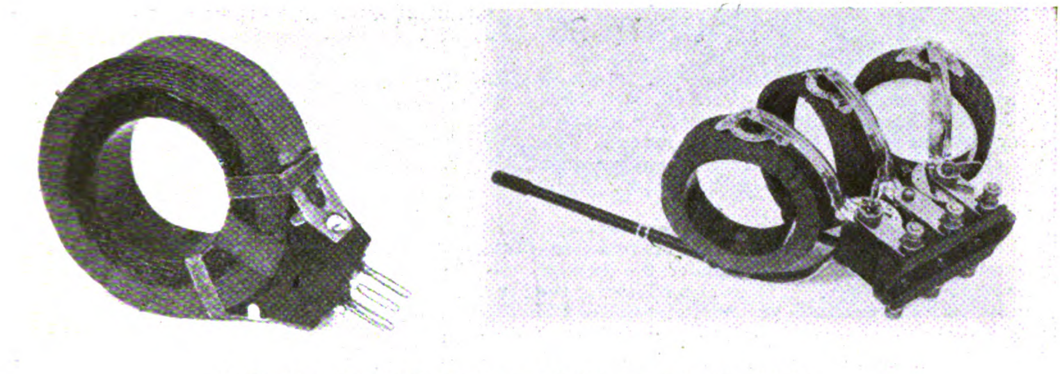
subject of tuning, we noticed one or two rejector circuits or wave traps, such as the Radio Instruments and Peto Scott eliminators.

It was encouraging to see a greater selection of mechanically and electrically sound variable condensers, two examples being the Burndept low loss condenser and a square low brass plate condenser by the Sterling Telephone Co., Ltd. Double condensers for tuning two identical circuits simultaneously were also shown by the Dubilier Condenser Co., Ltd., Fallons, and A. W. Gamage, Ltd.

Rheostats and potentiometers were present in abundance, some very excellent American types being shown by the Ashley Wireless Telephone

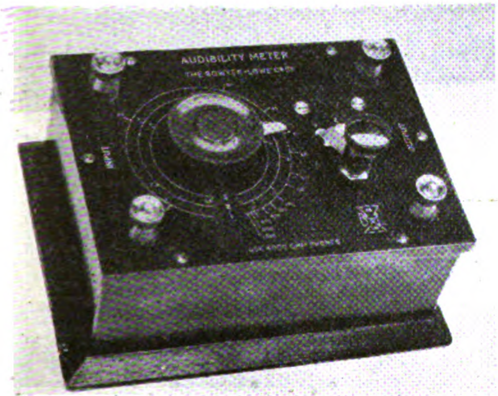


"Cosmos Strip," used for winding multi-layer coils.



An Igranic duolateral H.F. transformer and their new coils and coil holder.

Co., Ltd., and Igranic Electric Co., Ltd. A glass-enclosed filament rheostat by Houghton was new to us. Practically every stand must have been a gold mine to the "gadget" hunter, as gadgets were very fully represented, so fully, in fact, that it is impossible to deal with them in such a limited space. However, we must certainly mention "Clix," a universal connector, and also "Polar Blox," the latest constructional outfit. Crystals of the "-ite" variety were to be found on many stands, and we were interested to see "YA1," a real synthetic specimen which functioned excellently.

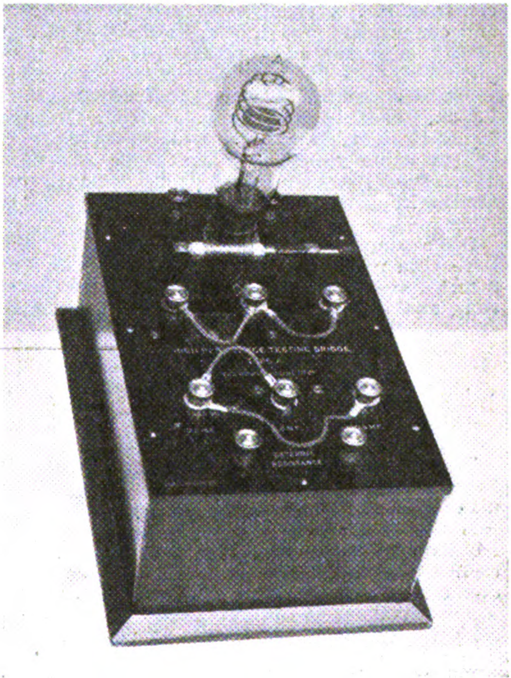


A useful apparatus for comparing signal strength.

So far as complete receivers are concerned, there was a marked tendency to mount them in cabinets designed to tone in with existing furniture schemes. Here we may mention the Jacobean "Efescaphone," the beautiful lacquer finish of the Sterling Telephone sets, the Roger Foster & Howell set in an imitation piano, the beautiful cabinet model of the General Radio Co., Ltd., and the combined gramophone and wireless set by Abbey Industries, Ltd. The actual circuit which seems to have found most favour in the majority of sets is the tuned anode, but several transformer-coupled models were to be found, and also one or two reflex circuits such as the smaller Marconiphone, the Radiax set, and the Climax monovalve.

In addition to actual wireless apparatus itself, we noticed an audibility meter and a neon resistance bridge. Both these instruments are made by the Bowyer Lowe Co., Ltd.

Last, but not least, amongst the varied attractions, we must mention the demonstration of



A neon resistance bridge in which measurements are taken by the flash interval.

broadcasting by the B.B.C. Although we were informed on very good authority that some most excellent reproduction was obtained, our own experience was that on more than one occasion the speech was of somewhat poor quality, due, no doubt, to the somewhat trying conditions.

One of our visitors described it as resembling an "elephant making a trunk call"!!

Business Brevities.

In our note last month describing the new instructional model of a two-valve set introduced by Messrs. George Philip & Son, Ltd., a printer's error made us refer to this as a 10-valve set. This was an obvious misprint; but we hope our readers will observe that this excellent model really describes a two-valve set.

* * *

A new book which will interest many experimenters has just been issued under the title of *The Radio Time Table*. This gives a full list of the transmissions from all the principal stations of the world during the 24 hours, so that an experimenter can see at a glance what to listen-in for at any hour of the day or night. The price is 6d., or post free 7½d. Any agent for EXPERIMENTAL WIRELESS, or from Percival Marshall & Co., 66, Farringdon Street, London, E.C.4.

* * *

A new list issued by Messrs. Burndept, Ltd., Aldine House, Bedford Street, Strand, London, W.C.2, covers 88 pages. It is divided into five sections and deals with "Ethophones" and other receiving equipment bearing the B.B.C. seal, home constructional receiving sets, auxiliary apparatus and components, and transmitting apparatus. It is fully illustrated, and is priced at 1s.

* * *

Mr. H. Saville, Delamere Works, Stretford, Lancs., sends us his 6 H.S. Booklet. It gives illustrations of a number of wireless and engineering specialities supplied by Mr. Saville, and also a directory of Amateur Transmitting Stations in the Lancashire district and their call letters.

* * *

Some samples of excellently-made basket coils have been received from Mr. F. Adcock, 39, Fore Street, Ipswich. These are known as the "Magna" coils, and are supplied in sizes suitable for wavelengths ranging from 100 to 10,800 metres. The special features of the coils are silk insulation, no wax, and rigid and regular windings. A list of sizes and prices may be obtained on application to Mr. Adcock.

* * *

Messrs. Lionel Robinson & Co., 3, Staple Inn, London, W.C.1, send us a leaflet describing the "Ella" battery charge for A.C. circuits. It is a simple form of vibrating rectifier of the full-wave pattern, and works from any lamp holder.

* * *

Two new lists have been issued by Messrs. Fuller's United Electric Works, Ltd., Chadwell Heath, Essex. No. 315 deals with wireless accessories, such as transformers, tone selectors, filament resistances, lead-in insulators, valve holders, potentiometers, fixed condensers, and coil holders. No. 250 B. covers the well-known "Fuller" accumulators for motor-car ignition and lighting, wireless and general purposes. Both standard plate type and block type cells are described.

* * *

A wide range of good-class components are described and illustrated in a new 42-page list issued by The Sterling Telephone and Electric Co., Ltd., 210-212, Tottenham Court Road, London, W.1. These include 'phones of various patterns, variometers, condensers, valves, transformers, switches, keys, aerial equipment, and other useful accessories. The list is No. 368.

* * *

Portable "Exide" Batteries are dealt with in the fourth edition of Catalogue P issued by The Chloride Electrical Storage Co., Ltd., Clifton Junction, near Manchester. A variety of types of cells are illustrated and described, including special high-tension batteries for wireless sets.

Experimental Notes and News.

The Postmaster-General, speaking at the Wireless Exhibition, said that 492,000 licences had been issued as the result of the recent campaign, or just four times as many as there were in March last. He also said that he was about to appoint a Broadcasting Committee, composed of representatives of the industry, the public and the Press, so that future Postmasters-General would not have to carry the whole burden on their shoulders.

* * *

Election results are to be broadcast between 10 p.m. and midnight on December 6 and December 7. The results will be issued simultaneously from all B.B.C. stations.

* * *

Dr. A. M. Low, writing in the *South Wales News*, says:—"I have already used a television machine of a crude sort. Placed 'looking' at a field, and with the twin apparatus one mile distant, the machine, piercing all obstacles, revealed the figures of men walking in that field. The vision, however, was so dim and vague that one could not distinguish such details as features or whether a cap or hat was worn by the individual."

* * *

It is reported that Mr. H. Knight, a Hull amateur, has recently received a complete church service broadcast from New York between 12.30 and 1.45 a.m. The congregational hymns, an anthem, the sermon and prayers, and the sound of the people leaving the church, were perfectly audible.

* * *

Hearing a football match being played 150 miles away is a stepping-stone towards seeing it. Students of Princetown University, New Jersey, recently listened-in to their team playing a U.S. Navy team at Baltimore, some 150 miles distant. The students gathered round on the lawn, where four big projectors were in place on the roof of a motor car, and the various happenings in the game were described by an observer on the spot.

Experimental Wireless

A JOURNAL OF RADIO RESEARCH AND PROGRESS

VOL. I, No. 4. JANUARY, 1924. 1s. NET.

Experimental Topics.

Trans-Atlantic Telegraphy.

DECEMBER, 1923, will always stand out as one of the stepping stones in the history not only of amateur experimental work, but of wireless progress in general. During the latter weeks some of the most remarkable transmissions ever recorded have been conducted, fuller details of which will be found elsewhere in these pages. It is only within the last few years that the problem of long-distance transmission has been approached from an entirely different view-point. Formerly, the tendency has been to erect gigantic stations using power of the order of some 50 kilowatts or more, and to operate these stations on extremely long wave-lengths. Recent events, however, seem to indicate that this system is now open to considerable rivalry, and its continuance will probably be a matter of some debate. Progress in short-wave transmission during the last few years has led up to a number of experiments on trans-Atlantic telegraphy using a directed beam with an input power of the order of one kilowatt. The success of these experiments has created considerable interest, but this accomplishment seems almost insignificant in light of the recent amateur performances. Mr. E. J. Simmonds, a regular contributor to EXPERIMENTAL WIRELESS, and one of the leading private experimenters in the country, has created what is surely a world's record in establishing two-way communication with a Mr. Dodman, of Summit, U.S.A., using a power of approximately 30 watts. The communication was conducted without the slightest difficulty, and it is not regarded in any sense as a freak performance. Previous to this accomplishment, we have news of Mr. Partridge and Mr. Hogg getting in touch with several American and Canadian stations on powers of approximately 100 watts. The workings were not confined to one or two short periods on one particular day, but were repeated on several occasions. There are two important deductions to be drawn from these events. It is clearly evident that the possibilities of short-wave low-power transmission are not yet fully realised, and are not likely to be so until further investigation has taken place, and, perhaps, it is not rash to suggest in the very near future, the shorter waves will be of greater use than the longer waves. What is more important, however, from the amateur point of view, is that these remarkable transmissions are primâ facie evidence of the value of private experimental work, and should serve to strengthen materially the amateur's position and his relationship with the authorities. While we are strictly opposed to the issue of transmitting licences to all who may care to apply for them, it is sincerely to be hoped that the genuine experimenter will be given greater facilities for further investigations. It is very gratifying to learn that many transmitting licensees are more than justifying their claims for a permit by doing such excellent work, and the fact that each year's

performance excels that of the previous year is a clear proof, not only of their capabilities, but of the value of their investigations.

Un-licensed Transmission.

It appears from some information recently received that there are now in existence several amateur stations which are actively engaged in transmission experiments without being in possession of the necessary permit. While we have no wish for unrestricted experimental work, we would remind those concerned that the very existence of the experimenter is dependent on the Postmaster General's regulations, and it is unnatural to expect him to grant greater facilities if those already in existence are so openly abused. Perhaps the un-licensed transmitter does not fully realise that by continuing his experiments he is prejudicing not only his own position, but that of every experimenter. He need not think that his whereabouts are a profound secret, known only to his unlicensed associates, for already in more than one case he has fallen a prey to the D.F. loop, and it now only remains for him to close down. The Postmaster-General is always prepared to consider any application for a transmitting permit if the reasons for use can be fully justified. If the unlicensed transmitter has in view some definite and useful research there is little doubt that he will be granted a permit. If, on the other hand, he does little else than fill the ether with poor reproductions of bad gramophone records, the sooner his station sinks into obscurity the better it will be for all concerned.

The New Strength Code.

For some considerable time it has been customary to record signal strength by the " R " code, in which there were no fewer than nine degrees of strength. This method of recording is obviously not absolute, being merely a comparison of standards which are subject to personal error. It is a matter of conjecture whether there is anything to be gained by using so many degrees, and the new "A" code, as it is termed, is confined to four degrees only, over which there can be no misunderstanding, and, in our opinion, it is adequate for anything but absolute measurement. Another useful feature of the code, full particulars of which were given in the last issue of EXPERIMENTAL WIRELESS, is that it shows the number of valves used for reception, and, therefore, gives a much clearer indication of the nature of the transmission. It is understood that many experimenters are now using this method in preference to the " R " code, which, it is hoped, will soon be universally superceded by the "A" code.

Terms and Definitions.

The British Engineering Standards Association has just issued a list of terms and definitions used in radio communication. The pamphlet, No. 166, is divided into various sections, and the whole field of wireless work is covered by some 600 definitions. Although most experimenters are fully conversant with wireless nomenclature, there are sure to be certain definitions over which there is considerable disagreement, and we advise our readers to refer to this most useful publication.

The Model Engineer Exhibition.

THE Seventh Annual Small Power Engineering and Scientific Exhibition, organised by the publishers of this journal, will be held at the Royal Horticultural Hall, Westminster, from January 4 to 11. Wireless equipment has always been a feature of the exhibits at this show, and the coming Exhibition will be no exception to the rule. But apart from the radio exhibits themselves, there will be numerous other items of special interest to wireless experimenters. Small lathes, precision tools, and workshop sundries of all kinds will be there in abundance, while general electrical apparatus will be strongly represented. Naturally Model Engineering will form a big section, and the many fine model locomotives, engines and boats, which will be on view will give the wireless visitor an insight into another kind of hobby which, in its way, is quite as interesting as his own. There will be some model railway tracks, 72 ft. long, on which passenger-hauling model locomotives will be constantly at work, and even if the radio enthusiast is wrapped up in the contemplation of some of the newer wireless gadgets in the trade section, his family or his friends will find much to entertain them in the Working Model Railway Enclosure. The Exhibition opens at noon each day, and closes at 10 p.m. The price of admission is 1s. 6d., which includes tax.

Microphone Amplifier and Control Circuits.

By ALAN L. M. DOUGLAS, M.I.Radio Eng.

Most experimenters are content to confine their attention to the adjustment of circuits rather than microphones Below will be found some practical suggestions for the adjustment of microphones for the transmission of music.

It is rather remarkable that, whilst so much experimental work is done by amateurs on telephony control circuits, they are generally content to accept as a basic exciter the ordinary Post Office type of solid-back carbon microphone.

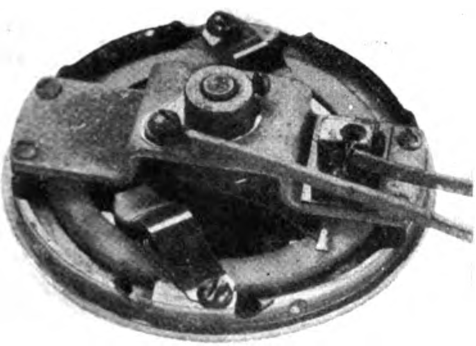


Fig. 1.—Illustrating the Construction of the solid back microphone.

Admittedly the great amount of research work which has been done on such microphones makes them very practical for voice frequencies about the middle register, but from a musical reproduction viewpoint they are vile. There are a number of reasons for this. First of all, the diaphragm of the ordinary Post Office microphone has a natural frequency of about 500. This means that sound-waves having the same frequency, plus or minus about 100, will cause the diaphragm to be energised most and so produce the greatest current changes in the granules. Then the diaphragm, although made of aluminium so as to be as light and as "dead" as possible, is much too thin, and is liable either to (*a*) respond to harmonics, or (*b*) rattle. Much of this could be cured by rigidly clamping the edges of the diaphragm instead of permitting the usual elastic suspension of rubber and springs to be used.

Again, the mica diaphragm carrying the insulated contact of the actual microphone button is much too thin, and is liable to respond on its own (especially at the edges) to high note frequencies which fail to attack the diaphragm proper. Then the granules should be finer and there should be more of them; the button can, with advantage, be packed almost full, but the carbon must be of an even character, and the granules, as far as possible, of the same weight and shape. The correct degree of packing is found by trial.

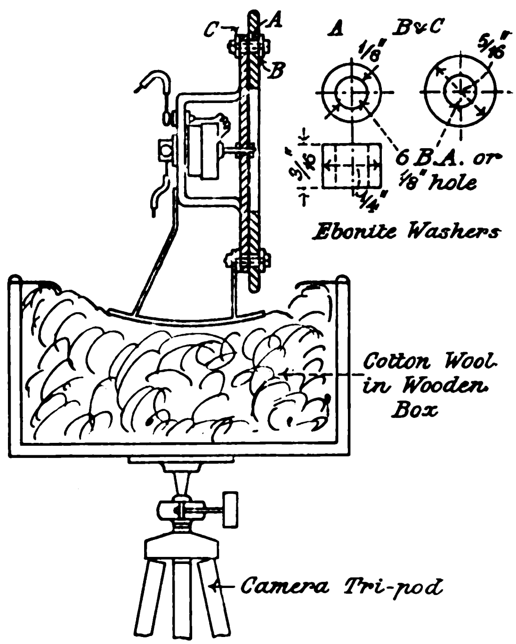


Fig. 2.—Showing a solid back microphone adapted for music transmission.

Now, much useful work may be done upon the transmission of music and similar items requiring great flexibility in the

microphone by the use of an ordinary Post at 6 volts. Natural frequency of the diaphragm is 500. Now, for the successful transmission of music the diaphragm must be made to have a natural frequency either above or

The average current consumption is ·03 amps. at 6 volts. Natural frequency of the diaphragm is 500. Now, for the successful transmission of music the diaphragm must be made to have a natural frequency either above or

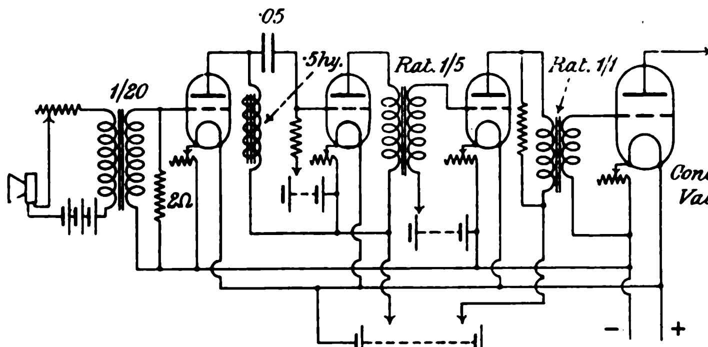


Fig 3.—A typical amplifier for musical frequencies

weighs ·17 oz. The mica diaphragm is ·0022 inch thick and weighs (with carbon contact) ·18 oz. The mica alone weighs ·03 oz. The carbon granules weigh ·08 oz., and when in place, with the button closed

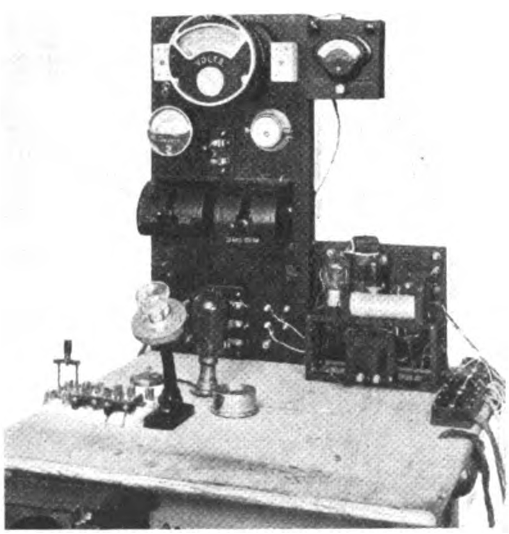


Fig. 4.—A general view of the music amplifier.

for action, so to speak, has a resistance of 17 ohms. This latter figure is approximate, being never twice exactly the same. The pressure exerted by the springs on the aluminium diaphragm is ·64 lb. each side.

below the highest or lowest musical notes; this is practically equivalent to saying above or below audibility. Both of these arrangements are employed in practice; both are equally successful. But for our purposes we will find a sub-audible natural frequency, the most useful, because it is difficult for the average experimenter to stretch the diaphragm until its frequency is raised to such a high figure.

To convert successfully the Post Office microphone we proceed as follows :—It must be remembered that I am dealing here with the transmission of gramophone records, as this is the form of music available to most of us. A gramophone record successfully reproduced is an achievement of which one may well be proud, as it is the most difficult conceivable thing to do well. By well here I mean as well as, let us say, 2LO.

To begin with, the metal diaphragm is removed, together with the tension springs, mica diaphragm, and centre contact button. The granules are emptied out and fresh ones obtained. Very suitable carbon may be obtained from the Western Electric Company. Next, the paper packing ring under the faceplate is scrapped, and a series of six equally-spaced holes drilled round the circumference of the plate where the edge of the diaphragm lies. These holes may be about $\frac{1}{4}$ in. diameter. The central domed portion of the faceplate should, if possible, be turned right out, as it forms a resonating

chamber, which causes "damping" in rapid musical passages.

The small holes just drilled must be carefully bushed with ebonite, and washers provided for front and back attachment. The bushes will only be 3-16th in. long (see Fig. 2). Six bushes and twelve washers are required. A diaphragm ·15 inch thick, and weighing approximately ·3 oz., must be prepared from hard sheet aluminium. This should be beaten out to reduce its resonant properties and to harden the metal, and then rolled absolutely flat. It is no use if it is kinked or dented, and these operations must be performed *cold*. The diaphragm may be enamelled on both sides to prevent corrosion and to minimise the small "room noises" from affecting the applied sound waves, and six ¼-in. holes must be carefully drilled around its edges to correspond exactly with the holes in the faceplate. As the holes in the bushes will only be ⅛ in., or 6 B.A., this size of screw should now be used to secure the diaphragm in position, great care being taken that (*a*) the paper insulating washer is in place, and (*b*) that the screws pass through the centre of the ¼-in. holes and do not touch the aluminium. The ebonite washers are, of course, placed under gramophone sound-box, the central hole (·13 inch) being already drilled. It does not matter if this is ·17 inch, as it will be if taken from a gramophone, as the diaphragm is securely clamped between the carbon disc and the brass washer with lock-nut and adjustment screw thereon. The capsule should be about seven-eighths filled with fine carbon granules, these being adjusted until

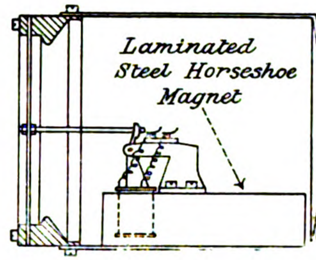


Fig. 5.—A suggested arrangement for a balanced amateur microphone.

the mean resistance of the microphone is approximately 300 ohms with the mica in position. This will mean that the output will be very small, but this is desirable, as it can be further amplified. As an example, with a two-stage amplifier about to be described the best position for gramophone

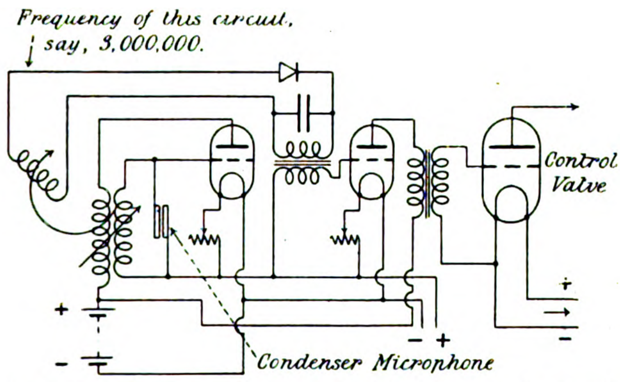


Fig. 6.—An electrostatic microphone circuit in which the modulated output of an oscillator is rectified by a crystal, and subsequently amplified.

the heads and the bolts of each screw and nut. This can all be gathered from Fig. 2. The centre hole in the diaphragm is ·13 inch.

The next step is the correct proportioning of the mica diaphragm. This should be cut from condenser mica of absolutely flawless grade ·05 inch thick, and should weigh ·09 oz. Better still, it may be cut from a transmissions (using a soft needle) will be from 6 to 10 ft. from the instrument, amplification being about 40 per cent. For speech with the same degree of amplification about 3 ft. from the faceplate will be found correct. The reconstructed microphone can be easily assembled, and the adjustment is soon found.

Now the microphone transformer should generally have a primary resistance equivalent to that of the microphone, but it will be found that, if this is carried out, pronounced voltage peaks will be encountered, even when the natural frequency of the diaphragm is only about 10 (as it is in the present case). The windings are, therefore, open to experiment, and the best results are obtained with the following data. A 6-ohm rheostat should be used in series with the microphone battery.

Core.		Primary Winding.		Secondary Winding.	
Length.	Diameter.	Gauge.	No. of Turns	Gauge.	No. of Turns.
$4\frac{1}{2}$ ins.	$\frac{3}{8}$ in.	22 S.W.G. D.S.C. Copper.	380	40 S.W.G. S.S.C. Copper.	20,000
28 S.W.G. soft iron wire, tightly packed, open ends.					

A resistance of about 2 megohms should be connected across the secondary winding to control further any peak voltages which may arise. This will also relieve the load when the microphone switch is opened, and prevent a possible sudden rush of current when the circuit is broken on the primary side. In a 100-watt transmitter I have personally experienced a flash-over of the control valve when the microphone circuit was opened, due to the absence of this resistance.

Core.		Winding.		Inductance Values.
Length.	Diameter.	Gauge.	No. of Turns.	
4 ins.	$\frac{1}{2}$ in.	40 S.W.G. S.S.C. copper.	3,000	·57 hy.
28 S.W.G. soft iron wire, tightly packed. This choke should *not* have a closed core.				

This microphone transformer is best incorporated into a low-frequency speech amplifier, such as is shown in Fig. 3. The third stage in this amplifier may be omitted if desired, but the coupling to the control valve must be by means of a 1 : 1 ratio transformer. This should have an impedance of about 4,000 ohms each winding, and the power transformers manufactured by the Sterling Telephone Company will be found excellent for this purpose. It will be seen that the coupling in the first stage is by means of an iron-core choke and low-frequency condenser. The choke may consist of the data given in the second table.

The coupling condenser can be of any value between ·01 and ·06 mfd., but ·05 gives extremely good results. The second stage coupling transformer may be of any standard make, but should work at a low flux density, and may, therefore, be of the Army pattern. The valves may be hard—the harder the better; small transmitting valves rated at about 20 watts would seem to give the clearest amplification. The resistance across the output side should be the same as that across the secondary of the microphone transformer, *i.e.*, 2 megohms. A standard grid-leak will serve excellently here. With the microphone just described this amplifier will be found to give about the right degree of modulation when used in a standard choke-control circuit, but the margin of control here is not great and care must be taken not to overdo it. The amplifying circuit will pick up the voice quite clearly from 20 ft. distant, with a minimum of room noises. The degree of control at this distance is, however, too deep, and the best working ranges are as previously mentioned. The amplifier is perfectly silent with correct values of H.T. and grid biasing batteries, and should prove useful for those experimenters who try a little land-line work on

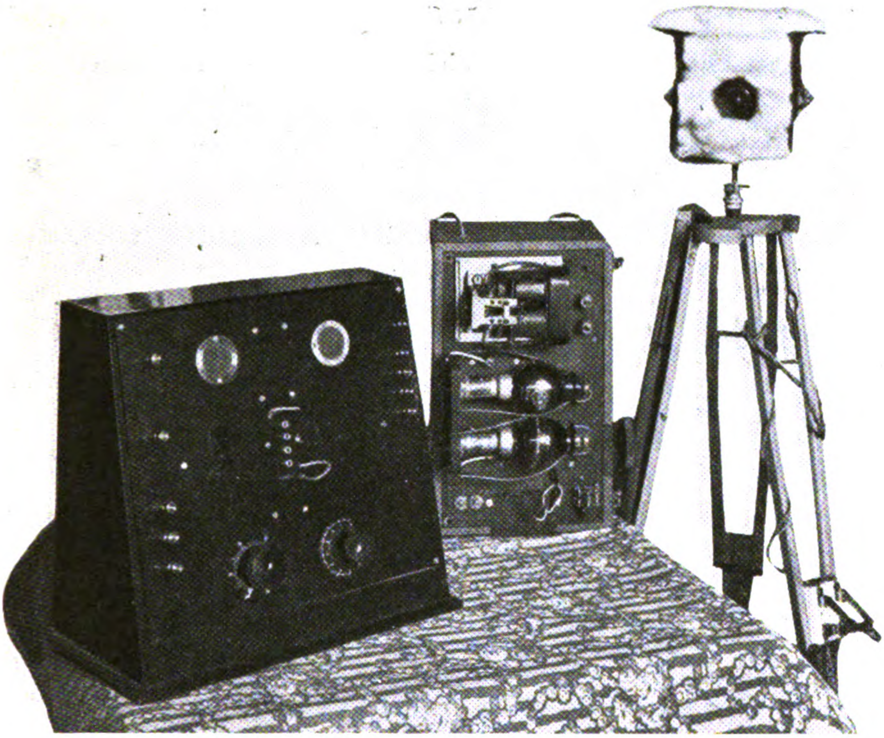


Fig. 7.—A general view of the converted microphone, amplifier, and control panels.

their own, or transmitting amateur theatricals and concerts. The flexibility of the amplifier when such a heavily-damped microphone is employed has enabled the writer to achieve considerable success with the above-mentioned enterprises.

Limitations as to space forbid my discussing the various types of microphone I had intended to, but why not an attempt at a microphone such as Fig. 5? This is a revised arrangement of the microphone employed at the London station, and should give excellent reproduction if carefully made. The great thing is to break away from the intermittent contact type of transmitter, and Fig. 5 presents one solution of the problem.

Then there is the electrostatic type. This is heavily laden with difficulties, but they could be overcome. The writer has used such an arrangement as is shown in Fig. 6, with great success at times, but it is very susceptible to "wash" from the main transmitter, and may do curious things if not suitably shielded. There is ample scope for research work on microphones, and I for one would welcome co-operation along these lines.

Directive Radio Telegraphy and Telephony.

By R. L. SMITH-ROSE, Ph.D., M.Sc., D.I.C., A.M.I.E.E.

During the last few years there has been considerable development in directional work, particularly with the use of extra short waves. There are obviously many applications of directional transmission, and we are giving below a general summary of modern methods and practice.

II.—DIRECTIONAL WIRELESS ON WAVE-LENGTHS ABOVE 100 METRES.

(a) The Theory of Direction-Finding Systems.

A DIRECTIVE system for either transmission or reception can be obtained by the use of vertical wire antennæ, making use of the instantaneous phase difference in space of the electro-magnetic field of an advancing wave. For example, if two vertical antennæ (Fig. 1) of height h, and separated by a distance d, are used for the reception of a wave of length λ arriving from a direction making an angle $90 - \alpha$ with the plane of the two aerials, the E.M.F.'s induced in the two aerials will be—

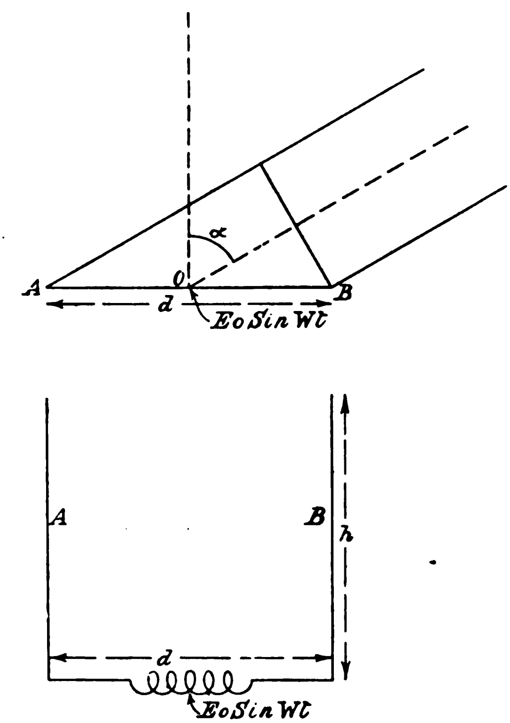


Fig. 1.—Two vertical aerials as a directional receiver.

$$\left.\begin{aligned} E_A &= h\,E_o \sin\left(\omega t - \frac{\pi d}{\lambda}\cos\alpha\right) \\ E_B &= h\,E_o \sin\left(\omega t + \frac{\pi d}{\lambda}\cos\alpha\right) \end{aligned}\right\} \quad \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

where $E_o \sin \omega t$ is the vertical electric field at the centre point o.

The available E.M.F. in the horizontal limb connecting the lower ends of A and B is thus—

$$\begin{aligned} E_C &= E_A - E_B \\ &= hE_o\ (2\cos\omega t \sin\frac{\pi d}{\lambda}\cos\alpha) \end{aligned}$$

and when d is small compared with the wave-length λ, this reduces to—

$$E_c = 2\,h\,E_o\ \cos\omega t\ \frac{\pi d}{\lambda}\ \cos\alpha \ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

The signal E.M.F. E_c arising from such a pair of aerials is, therefore, dependent upon α, and passes through zero for the value $\alpha = 90°$, *i.e.*, where the direction of the arriving waves is perpendicular to the plane of the aerials. The polar diagram of reception of such a system is shown in Fig. 2, where the vector r represents the intensity of signal received in the direction making an angle α with $O\ X$, the normal to the plane of the aerials.

Several experimenters worked on this method of spaced open aerials for both transmission and reception, and its principles were actually embodied in the original Bellini-Tosi direction-finder, using two pairs of such fixed antennæ and a radiogoniometer of a very similar pattern to that in use to-day.

In practice, however, it was found to be a great advantage to join the upper ends of the antenna A and B, making these into a

closed loop, Fig. 3, representative of the modern coil antenna. In the above analysis it was assumed that the electric field of the advancing wave was vertical, and that the only sources of E.M.F. in the system were the vertical antennæ A and B. This is not strictly true in most practical cases, since the advancing wave-front is seldom vertical, and it is well known that signals may easily be received on a horizontal aerial, for example, of the Beverage type. The horizontal component of the electric field will induce E.M.F.'s in the horizontal sides of the loop shown in Fig. 3, and these must be taken into account in a complete calculation of the received signal. The latter, however, can be more easily obtained if we utilise the magnetic field of the wave as the basis of our calculation.

Assuming that the wave front of the incoming wave is sensibly plane, let it be inclined at any angle to the earth's surface, and let the magnetic field lie in any direction in the wave-front; this constituting the most general case for the arrival of a single wave. Let the magnetic field at the point where the loop is situated be resolved into two components at right angles—the one horizontal and the other vertical. Then, since the plane of the loop is vertical, the latter component can never link with it, and may, therefore, be neglected as regards its effect on the loop.

Let the direction of the horizontal component of the magnetic field make an angle of $90° - \alpha$ with the plane of the loop, as in Fig. 4, and let its maximum value be H_m; also let E be the maximum value of the E.M.F. induced in the loop. Then, if the length of the waves be great compared to the linear dimensions of the loop—

$$E_m = KA \cos \alpha \qquad \text{(3)}$$

where A is the area of the loop and $K = \omega H_m$, ω being the periodicity corresponding to the waves.

When the loop is turned into such a direction that the E.M.F. induced in it is zero, we shall have $\alpha = 90°$, and the loop will then lie in the vertical plane containing the direction of the resultant magnetic field in the wave-front. In certain common cases, subsequently discussed, this plane is perpendicular to the vertical plane containing the direction of travel of the waves, and from this fact arises the possibility of utilising the arrangement as a direction finder.

(b) The Single-Coil Direction-Finding System.

The single-coil system is a very close approximation to the simple theoretical case already discussed, its chief points of departure being as follows:—

(1) The coil usually has several turns instead of a single turn, and the separate turns cannot occupy the same space.
(2) A tuning condenser and detecting apparatus are usually connected in the circuit.

As regards the first point (1), if it could be assumed that the several turns were all

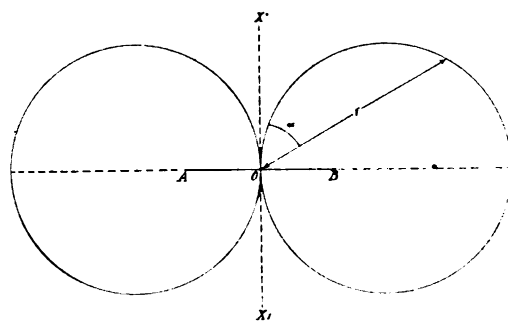


Fig. 2.—Polar curve diagram of reception of aerial system in Fig. 1.

condensed into the space occupied by a single turn we should simply get, instead of (3)—

$$E_m = KP \cos \alpha \qquad \text{(4}$$

where P is the quantity (area × turns) for the coil.

In practice, however, the turns cannot coincide. They are, therefore, spaced either in a series of equally dimensioned loops in nearly parallel planes (box type coil), or are wound spirally in the same plane (pancake-type coil).

In the case of the pancake winding the law expressed in equation (3) still holds good, but the quantity A must now stand for the effective or mean area of the coil.

In the case of the box coil this is usually wound spirally with a slight "skew" on the winding, which may give the effect of an equivalent turn in the plane of the coils'

axis. The error so introduced, however, is usually only a fraction of a degree, and this may be entirely eliminated by a slight adjustment of the pointer on the coil, or by adopting a special mode of winding in which each turn is accurately located in a single plane.

As regards (2) above, in the practical use of such a single-coil system for the determination of direction, a variable condenser is introduced across the ends of the coil and adjusted to give resonance to the incoming waves. The resulting alternating potential difference across this condenser is then employed to operate the detecting amplifier arrangement to give audible response to the incoming waves (Fig. 5).

When the above condenser is connected to the loop and the resonance condition obtained, the current in the loop from equation (4) will be—

$$I_m = \frac{E_m}{R} = \frac{KP \cos \alpha}{R} \quad \text{......................} \quad (5)$$

where R is the effective resistance of the loop under the prevailing radio conditions. The

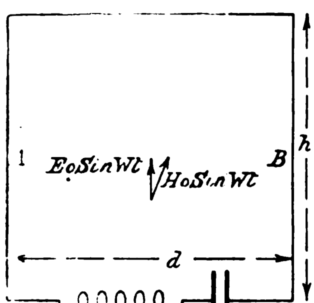


Fig. 3.—Closed loop directional receiver.

value of R depends not only upon the dimensions of the loop and the frequency being employed (*), but also upon the nature and circuit of the detecting arrangements (†).

The value of the P.D. across the condenser resulting from the current I_m will be—

$$V_m = \frac{I_m}{\omega C} = \frac{H_m P \cos \alpha}{RC} \quad \text{....................} \quad (6)$$

* A. S. Blatterman, "Theory and Practical Attainments in the Design and Use of Radio Direction-Finding Apparatus Using Closed-coil Antennas," *Journal Franklin Institute*, Vol. 188, pp. 289–362, 1919.

† J. Hollingworth, "Notes on the Design of Closed-coil Receiving Sets," *Wireless World and Radio Review*, Vol. 10, pp. 351–354, 1922.

where C is the capacity of the condenser at resonance.

It is evident, therefore, that the alternating potential difference applied to the detector varies with the orientation of the coil in precisely the same manner as the E.M.F. induced in the coil.

Two disturbing features, however, arise from the connection of the detecting apparatus, usually a combined amplifying-detecting arrangement of triodes. Firstly, the leads and whole circuit of the latter may pick up a small E.M.F. from the incoming waves, which will be independent of the orientation of the coil. While this E.M.F. may be small compared with the maximum value of V_m (*i.e.*, when $\cos \alpha = 1$) it may be quite sufficient to give a very audible signal when $V_m = 0$

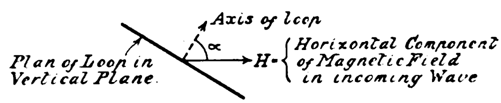


Fig. 4.—Plane vertical loop in path of electro-magnetic waves.

(*i.e.*, at $\cos \alpha = 0$). The result will, therefore, be a "blurring" of the zero of V_m into a more or less ill-defined minimum, which may considerably spoil the accuracy of the determination of the position of the coil for which $\alpha = 90°$. Secondly, due to the capacity to earth of the valve apparatus connected across the condenser, vertical capacity currents will flow to earth from the two vertical sides of the coil. In general, these currents will be unequal, due to the capacity to earth of the grid of the first valve being much smaller than that of the filament of the first valve with its associated batteries (compare Fig. 5). The inequality of these two currents results in a P.D. across the condenser G, even when there is no circulating current in the coil itself. Dependent also upon the inductance of the vertical sides of the loop and their capacity to earth, the phases of these currents will vary, but in general the resultant P.D. produced across the condenser by these currents is practically in quadrature with that produced by the circulating currents, as evidenced by the ill-defined zero of signal strength which is obtained on a coil possessing appreciable "vertical" or "antenna" effect. Another result of this vertical effect on a rotating coil system is that, in a complete rotation, the two minima of signal strength

are not exactly 180° apart, due to the non-directional properties of the superimposed P.D. resulting from the above antenna currents.

Various means of overcoming this defect on the single coil direction-finder have been suggested, one of the most successful being the use of a compensating condenser connected between the grid of the first valve and earth, by which the smaller capacity C (Fig. 5) is increased to be equal to C_1. In this case the two "antenna" currents become equal and produce no resultant P.D. across condenser C. Another very effective method consists in the use of a suitable screen surrounding the whole of the coil receiver and operator.

(c) The "Bellini-Tosi" Direction-Finding System.

In this system two large loops, usually of a single turn and of rectangular or triangular shape, are erected with their planes at right angles. In series with each loop is connected a small field coil. These two field coils are also mounted with their planes at right angles and preferably parallel to the planes of their respective loops, and a small search coil is pivoted so as to rotate within them. The axis of the search coil carries a pointer which moves across a horizontal circular scale divided in degrees.

The aerial loops and field coils of such a system are represented diagrammatically in Fig. 6 (*a*) and (*b*). Consider a wave front of the same general type as assumed for the case of the single coil and let the horizontal component of its magnetic field make an angle $(90-\alpha)$ with the plane of the loop A. As before, the vertical component cannot affect either loop, and so may be neglected. Applying equation (1) above to this case, and employing the same notation, we have—

$$E_m{}^1 = KA \cos \alpha$$
$$E_m{}^{11} = KA \sin \alpha$$

where $E_m{}^1$ and $E_m{}^{11}$ are the circulating E.M.F.'s induced in the loops A and B respectively and the area A of each loop is assumed to be identical.

Now, the magnetic field produced by the two field coils will be in the direction of their axes and proportional in magnitude to the current in each loop; that is, assuming an identity of the electrical constants of the loops whether they be tuned or untuned, proportional to $E_m{}^1$ and $E_m{}^{11}$ respectively. Hence, assuming the search coil is so small that the field is sensibly uniform over its area, we have:—

$$\left.\begin{aligned} H_m{}^1 &= K^1 H_m \cos \alpha \\ H_m{}^{11} &= K^1 H_m \sin \alpha \end{aligned}\right\} \qquad (7)$$

where $H_m{}^1$ and $H_m{}^{11}$ are the fields in question and K^1 is a constant depending on the area and constants of the loop circuits and the frequency of the waves. It is clear that the resultant of these two components $H_m{}^1$, $H_m{}^{11}$ will have a value—

$$H_m{}^{111} = K^1 Hm \qquad (8)$$

and will lie in direction making an angle α with the axis of the field coil A.

Thus a field is obtained from the field coils reproducing, as it were, in miniature the main field in which the two loops are situated, *i.e.*, the strength of the field is some definite fraction of the main field which is independent

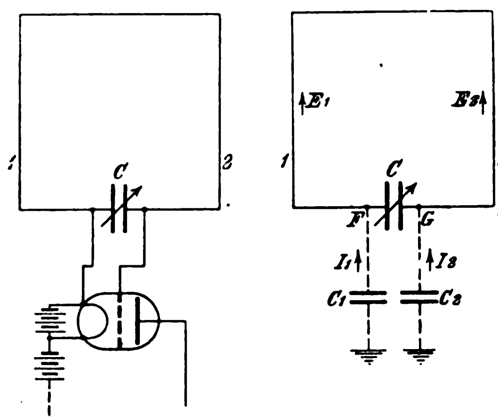


Fig. 5.—Arrangement of coil with tuning condenser illustrating capacity effect due to triode and its batteries.

of the direction of arrival of the waves relative to the loops, while the direction of this field makes, with the axis of the field coil A, the same angle which the main field makes with the loop A.

Hence, the search coil turning within the field coils is equivalent to a single rotating coil directly receiving the energy of the waves. It is thus possible to determine the direction of the waves by rotating the search coil to find the position where the currents induced in it are zero or a minimum.

The Bellini-Tosi system is thus in theory exactly equivalent to the ideal single-turn rotating loop. Like the rotating coil direction-finder, it is liable to a certain amount

of "antenna" effect; that is, the P.D. across the detector may not be entirely due to the circulating E.M.F.'s in the loops for the same reason, as in the case of the rotating coil. It may also be noted that the necessity with this system for exact similarity of the two loops, with their circuits and their accurate setting at right angles to one another, introduces a number of possible sources of error (due to non-fulfilment of these conditions) which are not present in the case of the rotating coil system.

(d) The Robinson System.

In this system the two coils A and B (Fig. 7) are fixed rigidly at right angles and pivoted about a vertical axis o.

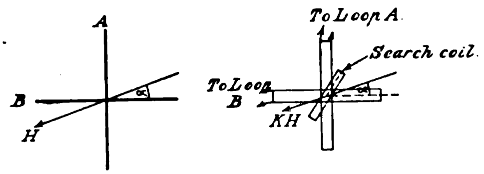


Fig. 6.—Schematic diagrams of Bellini-Tosi System.

The two coils are connected in series, and one of the coils can be reversed with regard to the other by means of a switch.

Let area turns of coil A be P.

Let area turns of coil B be Q.

Let H_m make an angle $(90-\beta)$ with the effective plane of the coil A. Then, if $E_m{}^{1}$ and $E_m{}^{11}$ be E.M.F.'s in A and B respectively, and there is no mutual induction between the two coils, we have—

$$E_m{}^{1} = KP \cos \beta$$
$$E_m{}^{11} = KQ \sin \beta$$

But since the two coils are in series, we have for the resultant E.M.F. in the circuit—

$$E_m{}^{111} = K\,[P \cos \beta \pm Q \sin \beta]$$

The sign in the bracket being negative or positive, according to the position of the reversing switch.

If now we choose an angle φ such that—

$$\tan \varphi = \frac{P}{Q}$$

we can write—

$$E_m{}^{111} = K\ (\cos \beta\ \cos \varphi \pm \sin \beta \sin \varphi)\ \sqrt{P^2+Q^2}$$
$$i.e.,\ E_m{}^{111} = K\ (\sqrt{P^2+Q^2})\ \cos\ (\beta \pm \varphi) \ldots\ldots\ldots\ldots(9)$$

but this is of the same nature as the expression obtained in (3) for the single-turn loop, for it can be written—

$$E_m{}^{111} = KP^{11} \cos \alpha$$
where $P^{11} = \sqrt{(P^2)+(Q^2)}$; and $\alpha = (\beta \pm \varphi)$

From this it can be seen that the system is equivalent to a resultant single coil with area turns $= \sqrt{P^2+Q^2}$ displaced by a fixed angle $\pm \varphi$ from the coil A, where—

$$\varphi = \tan^{-1} \frac{P}{Q}$$

This movement of an imaginary single coi by operating a switch is very similar to the swinging of a single frame or search coil of a radiogoniometer.

The angle is changed from $+\varphi$ to $-\varphi$ with relation to the coil A as the switch is reversed.

This resultant coil may be obtained by adding vectorially the area turns of the two coils in the manner shown in Fig. 8.

It is then clear that each time the switch is reversed it is equivalent to displacing a single coil suddenly through an angle of 2φ. If then, as in the method of operating the direction-finder, the whole system be rotated until a position is found in which the signal strength is equal in both positions of the switch, the resultant coil will be alternating between two positions symmetrical about its maximum or minimum position; that is to say, the coil must then lie with its plane parallel to H_m. In this way, therefore, it is possible to determine the direction of arrival of simple types of wave fronts. The angle of "swing" (2φ) of the resultant coil can be made the most suitable value by correctly choosing the ratio of P/Q.

(e) The Use of the Three Systems.

On account of the similarity in fundamental principle of these three systems of direction finding it is, therefore, to be expected that the results obtained by them are of a similar order of accuracy. Concentration on the details of design and construction of the apparatus, and judicious application of the principles of screening, has resulted in the elimination of many spurious effects leading to instrumental errors, which can now be reduced to a negligible magnitude for most practical purposes. The Bellini-Tosi system appears to have received most attention in this respect, and in many cases for shore station work it has

superiority in regard to robustness, ease and quickness of operation and detection of unreliability of the readings obtained. Where, however, portability and low cost are of great importance the single rotating frame is an excellent substitute. In many cases the Robinson system can be used with equal advantage, and it is greatly superior

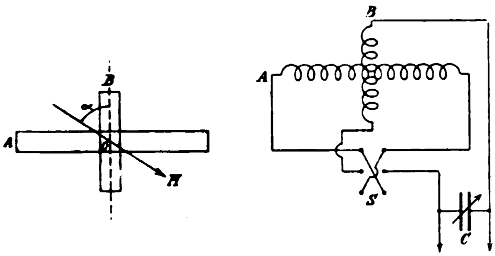


Fig. 7.—Plan of coils and diagram of connections of Robinson System of D.F.

to the other two systems in the presence of a large external noise which makes the detection of the minimum very obscure. For further details of the arrangements and uses of these directive systems the reader may be referred to text-books on the subject.§ Also in a recently published report of the Radio Research Board,¶ the above theory of the systems is considered in somewhat greater detail, and the conclusions are confirmed by a large number of results obtained in an experimental comparison of direction-finders.

(f) What is Indicated by a D.F. Coil.

From the theory of the closed-loop direction-finder given above it is seen that when the coil is rotated about a vertical axis until the strength of the signal in the telephones becomes zero or is reduced to its minimum value, the coil is then set with its plane parallel to the horizontal component of the magnetic field of the arriving wave. What is required in practice, however, is to determine the horizontal direction along the earth's surface from which waves arrive. Now, in the arriving electro-magnetic wave we know that the plane of the wave-front is perpendicular to the direction of propagation, and also that both the electric and magnetic fields lie in the wave-front and are at right angles to each other. If the direction of propagation of the waves is horizontal, then the wave-front is vertical, and all components of the magnetic field lie in the wave-front. The vertical coil placed in the position of minimum signal strength will, therefore, have its plane parallel to the wave-front, and the direction of the incoming waves will, therefore, be perpendicular to the plane of the coil. Hence, in this case the D.F. coil will indicate the direction of the arriving waves, whatever may be the direction of the magnetic field in the wave-front. The above condition of a vertical wave-front and horizontal propagation applies to the case of waves travelling over the surface of a perfect conductor, and for most practical purposes it is applicable to the propagation of wireless waves over sea-water.

When, however, the waves are travelling over a bad conductor such as dry earth eddy currents are set up which involve losses, and there is consequently a continual feeding of energy into the ground material. Resulting from this, the direction of propagation is inclined slightly downwards below the

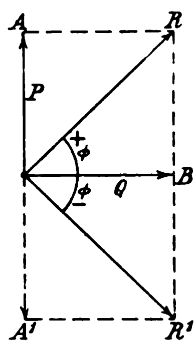


Fig. 8.—Direction and relative magnitude of resultant coil in Robinson System.

true horizontal, and the wave-front is consequently tilted forward in the direction of travel. Unless the magnetic field in this wave-front is entirely horizontal the horizontal component will not be perpendicular to the direction of travel of the waves, and the rotating coil will not necessarily indicate the direction of the arriving waves.

§ L. H. Walter, "Directive Wireless Telegraphy," 1921. (Sir Isaac Pitman & Sons, Ltd.) R. Keen, "Direction and Position-Finding Wireless," 1922. (The Wireless Press, Ltd.)

¶ R. L. Smith-Rose and R. H. Barfield, "A Discussion of the Practical Systems of Direction-Finding by Reception," Radio Research Board, Special Report No. 1, 1923. (H.M. Stationery Office.)

Generalising from the above, it is seen that what is actually determined from the rotation of a coil about a vertical axis is the direction of the horizontal component H of the magnetic field of the arriving waves. To determine the horizontal direction D from which the waves arrive it is necessary to know the angle between D and H. Practical experience with direction-finding has shown that in the majority of instances it is justifiable to assume that D and H are at right angles. This condition, however, can only hold for the two cases discussed above, *viz.*, first that the direction of propagation is strictly horizontal, or, second, that the wave is polarised such that the magnetic field is horizontal. The former case implies that the wave-front is vertical, whereas the latter imposes no condition as to the inclination of the wave-front.

It is evident, therefore, that absence of directional error in the readings of a frame coil direction-finder does not indicate anything very precise about the advancing wave-front or the inclination of the magnetic and electric vectors therein. The wave-front may be tilted forward at any angle, provided that magnetic field remains horizontal, or if the wave-front remains vertical the magnetic field may be inclined at any angle therein without giving rise to any error in the indications of the direction-finder. From the theoretical discussion correlating the systems of direction-finding it is evident that the above remarks in reference to a single frame coil apply equally well to the Bellini-Tosi and Robinson systems.

[*To be continued.*]

Radio Station 6UV

Amateur transmission stations usually show a marked dissimilarity in circuits, systems, and apparatus employed. This is due no doubt to the fact that many experimenters build their sets as a result of their own investigations. In order that experimenters may become acquainted with the work of others, details of stations embodying novel methods and circuits would be welcomed in these pages.

THIS station is located in Berkhampsted, Hertfordshire, at an elevation 500 feet above sea-level on the ridge of the Chiltern Hills, and is so placed that it is almost entirely free from screening either by natural or artificial objects.

Until the early part of the current year the station, which was first erected in 1912, and was equipped for reception only, was situated in a lower part of the town in a position far from ideal for transmission purposes.

This is mentioned because at this time the writer, in considering a site upon which to build a house, was fortunate enough to secure a position on the highest ground in the neighbourhood, giving considerable facilities for serious radio work.

The aerial, which is designed primarily for 200 ms. transmission, is of the twin inverted L-type, consisting of 7/20 H.D. copper, each strand being enamel insulated, and runs due North and South, each wire being insulated with three large porcelain insulators in series, the bridles of each of the 10 ft. spreaders being also broken with insulators.

The total length from free end to lead-in terminal is 120 ft., the measured fundamental wave-length being 175 metres, which in practice, owing to the employment of a counterpoise, is reduced to approximately 170 metres.

The aerial is slung from a 40 ft. wooden mast at the N end (shown in Fig. 1), and by a similar mast 45 ft. high at the S end. Each mast is stayed with ½-inch wire rope, the anchor blocks for the stays and also the mast housings being concrete, sunk to a depth of 3 ft. This is necessary owing to the exposed position of the station and prevalent N.-W. gales.

A six-wire counterpoise is used directly

under the aerial roof, each wire being spaced 2 ft. and 8 ft. above ground, and the whole fanned out to a distance of 20 ft. beyond each mast. The counterpoise lead can be seen in Fig. 1 alongside the main mast, but the counterpoise itself is not shown, as the photograph was taken before this was constructed.

Owing to the absence of earthed bodies the mean effective height of the aerial is 11·4 metres, and the capacity works out at approximately 0·00032 mfds.

The actual lead-in and main earthing switch are shown in Fig. 2, which also shows the 2-inch diameter mica tubes built into the wall as lead-in tubes. This photo also shows clearly the protection afforded to the lead-in insulators against rain by the overhanging gable.

On 195 metres, which is the normal operating wave-length, the radiation resistance is 4·8 ohms, and on 440 metres—the alternative wave for which the station is licensed—1·15 ohms. These combined with the ohmic and absorption losses give a total aerial resistance for the two wave-

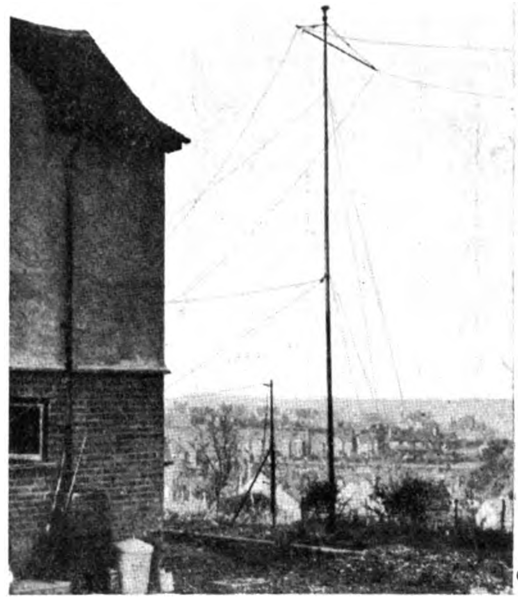


Fig. 1.—40 ft. mast and counterpoise lead.

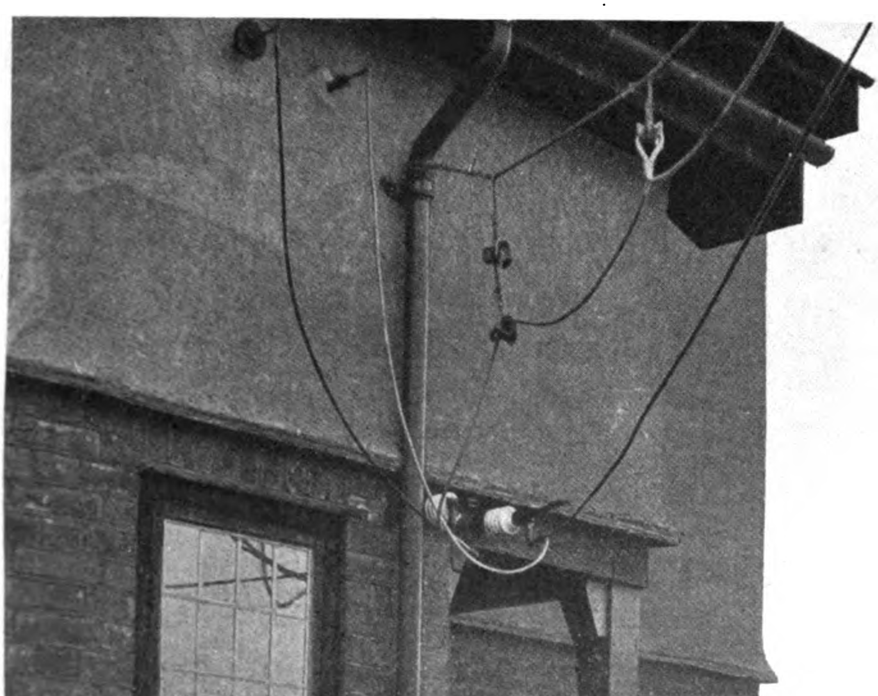


Fig. 2.—Aerial and counterpoise leads in, showing earthing switch.

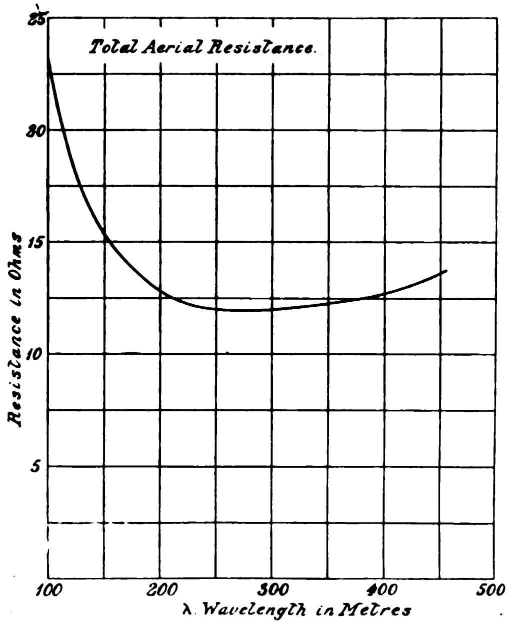


Fig. 3.—Total aerial resistance curve.

lengths of 13 and 13·4 ohms respectively, and as a matter of interest the total aerial resistance curve is given in Fig. 3.

Power for transmission is taken from a B.T.-H. 1,000 V.D.C. generator illustrated

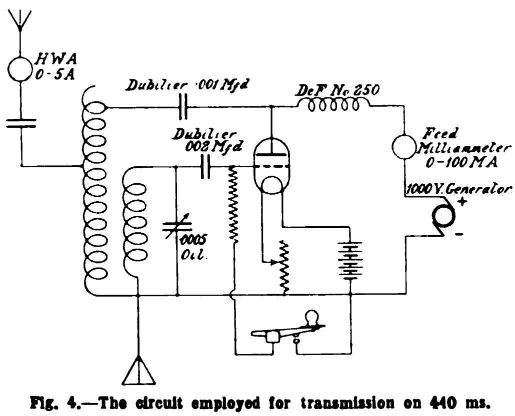


Fig. 4.—The circuit employed for transmission on 440 ms.

in Fig. 6, which is capable of giving 100 watts on continuous rating. This machine, originally an R.A.F. wind-driven plant, is run as a motor-generator from the house-lighting system, taking 8 amps. 16 volts on full load.

The transmitter itself is shown in Fig. 5, and is of the reversed feed-back type, the circuit diagram being shown in Fig. 4. All condensers used are of Dubilier manufacture with the exception of the oil immersed grid variable, which is ex-Navy, calibrated direct in jars. The radiation meter is a Sullivan 0—5 amp.

As a stand-by against failure of the main generator, an ex-Army T.v.T. unit is installed—seen on the extreme right of Fig. 5—for Tonic Train work, and will give

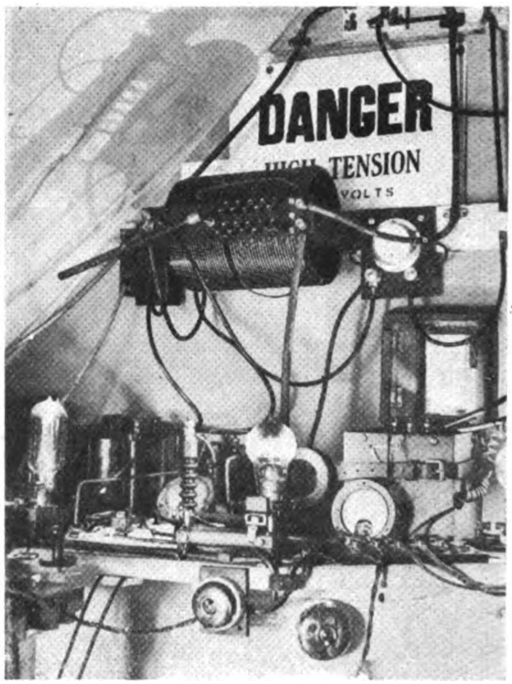


Fig. 5.—Near view of the transmitter in use at 6UV.

0·5 amp. in the aerial at 440 ms. The main inductance, with interior rotating grid coil, can be seen on the wall, and a "close up" of this unit is given in Fig. 7.

For straight C.W. a 40-watt oscillator valve is employed, the output of which can be modulated for speech by means of another 40-watt valve, the choke control shunt feed method being employed. When changing over from speech to C.W., the modulating valve is automatically cut out of circuit, the speech choke being at the same time short-circuited. A continuously variable grid-leak of the liquid type is used, giving very critical values of radiated power.

With a measured 10-watts input to the

valve, 0·8 is radiated on 195 metres, and 0·85 on 440 ms., both these figures being for straight C.W.

The receiving equipment, which is not shown in the illustrations, consists of a standard Mark III * tuner and 3-valve receiver (1 H.F. Det. and Note Mag.) for general work; a Marconi-type 55—7 valve amplifier arranged for supersonic working being used for long-distance traffic, and when QRM is bad a 3-valve receiver is employed of the type described by the writer in the December issue of EXPERIMENTAL WIRELESS.

Within the last month extensive trials of the Colpitts circuit have been carried out on 195 metres, with the result that it is proposed in future to use this circuit on the short wave, retaining the present transmitter solely for 440 ms. traffic.

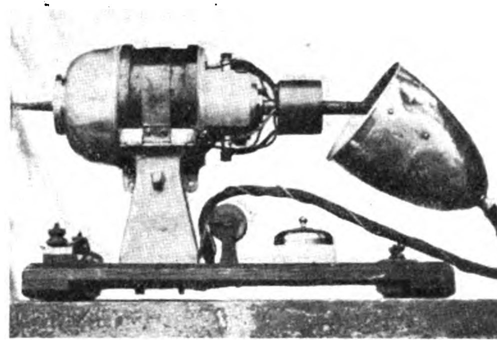


Fig. 6.—B.T.-H. 1,000-v. generator, showing main H-T. condenser.

In conclusion the writer would welcome reports from other stations who may hear 6UV.

G. L. MORROW.

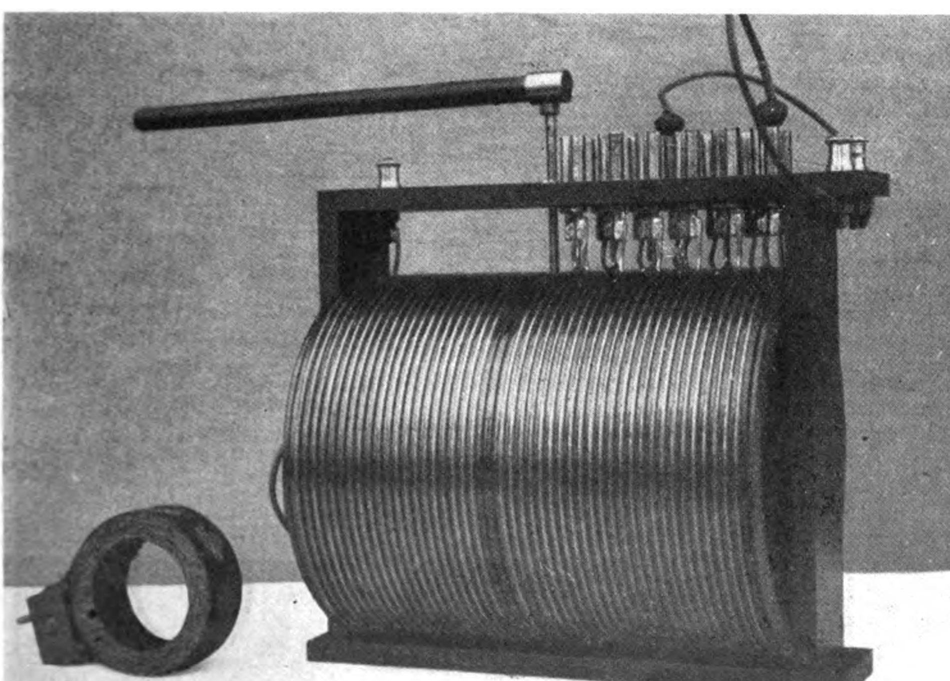


Fig. 7.—Transmitting inductance with 250 Igranic coil, showing relative sizes.

Frequency Transformers.

By H. T. DAVIDGE.

Although the problem of frequency multiplication presents many difficulties from a practical point of view it occurs in many branches of radio work, and the following summary should be of great interest.

THE problem of conversion of an alternating current at one frequency into alternating current of another frequency arose long ago. It has never been an easy problem, and only partial solutions exist even now if variation of frequency and economy are both essential. An obvious method for a constant ratio of the two frequencies is to use an A.C. motor

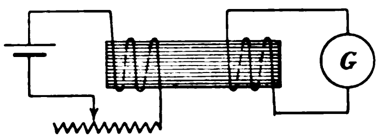


Fig. 1.—An alteration of the rheostat causes a current to flow through G.

coupled to an A.C. generator having the different required frequency, but this is cumbrous, expensive and invariable. The generator poles might, however, be in groups giving a twofold or higher ratio if desired. One method, which is in a sense frequency transformation, is the well-known heterodyne method for the reception of continuous wave signals. As an analogy a tuning-fork, for example, may be sounding a note of frequency 500 per second, and, audible with it, another fork having a frequency of 480 per second. The result of the combination of the two oscillations is a resultant wave which has peaks and hollows greater than either of the constituent waves, the peaks occurring with a frequency of 20 per second. Thus we have converted by this arrangement two different high-frequency oscillations into one of a very much lower frequency. The frequency of the beat note is simply the difference between the frequencies of the two given notes, and it is obvious that the same beat frequency may be obtained when one of the given notes is either above or below the other by the same amount. This method is now applied to detect an inaudible frequency by locally generating another inaudible frequency, but differing somewhat from the incoming one so as to produce an audible beat frequency so long as the other two are oscillating together. To thus cause two oscillations, both above the upper limit of human audition, to combine together and make a note of a musical character is one of the most ingenious methods for detecting ether waves. It, of course, necessitates an apparatus for making with certainty waves of nearly the same frequency and amplitude as those we wish to receive. Frequency changers however are in practice made on quite different principles which need no local generator to co-operate with the incoming current and the usual effect made use of is the magnetisation of an iron core by an electric current. In connection with the early days of telephony it will be remembered that if we take two ordinary

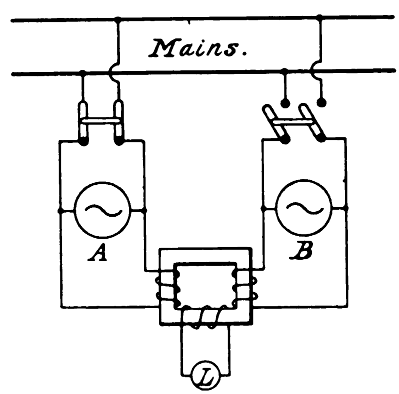


Fig. 2.—An arrangement for synchronising two alternators.

telephone receivers and connect them by lines without any battery, then on speaking into one, the other repeats the sounds at the distant end. The motion of the iron diaphragm at the one end generates *alternating* currents which cause corresponding motions of the diaphragm at the

other end. When the microphone and induction coil are added, at the sending end only, the process involves a *continuous* current in the microphone circuit, varied in strength by variation of resistance of the carbon granules. This current never reverses, but passing through the primary of an induction coil it causes strengthening and weakening of the flux in the iron core, and thus generates *alternating* current in

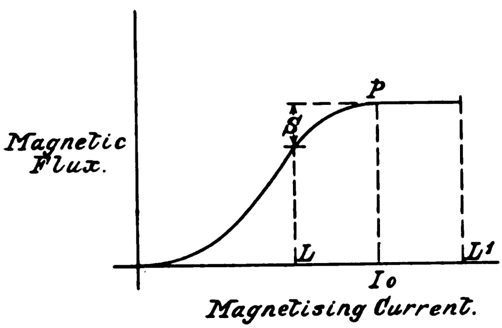


Fig. 3.—A typical magnetisation curve for iron.

the secondary or line circuit. Thus variation of magnetic flux always leads us to an alternating current. The same effect is found in the armature of a D.C. dynamo, but the brushes so arrange matters that unidirectional current only comes outside. This effect of change of flux may be made clear by a simple experiment. If an iron core (Fig. 1) has two coils upon it, one connected through a rheostat to a battery and the other to a galvanometer, we find that when the rheostat slider moves so as to increase the battery current there will be a current in G in one direction, while when the rheostat slider moves so as to diminish the battery current there will be the opposite current in the galvanometer. Thus variations up and down in a continuous current by the use of an intermediary magnetic flux cause alternating current in another circuit.

An application of the principles of the magnetic flux in a transformer and the beats due to two slightly different oscillations occurring together is found in the synchroniser used for coupling two alternators in parallel to the same mains on a switchboard. Suppose the frequency of the station to be 50 and machine A is already running. The load is increasing and it is necessary to insert B in parallel with A. Before a second alternator can be connected in parallel to the mains, not only must the voltage of the second machine equal that of the first—as in direct-current machines—but the phase of each must be the same; hence the need for a synchroniser. The type which illustrates our present problem is connected as follows: A transformer has three windings on its core, one connected to machine A, one to machine B, and a small secondary to a pilot lamp.

The two primary coils may be either wound similarly or oppositely. The connections are shown in Fig. 2. If similarly connected then when machines A and B are in phase the magnetic flux swings to and fro round the core with maximum energy, and the pilot lamp gives maximum light. If the two coils are oppositely wound then when A and B are in phase the magnetic flux due to one is exactly equal to that due to the other and the lamp remains dark. The procedure is then, using the bright lamp method, as follows: Machine A alone causes the lamp to glow, but when B is put on, out of phase to begin with, the light of the lamp oscillates. The attendant then adjusts the phase of B, and as it becomes nearer the right position beats of light occur as in sound, the frequency of the beats

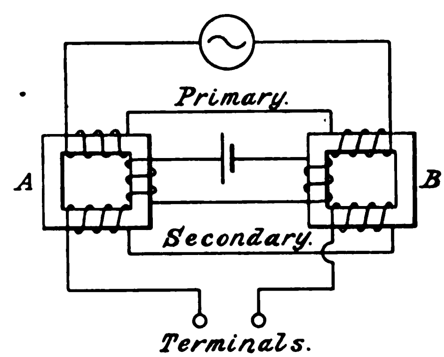


Fig. 4.—A frequency raiser due to Arco and Meisner.

growing less and less until the lamp remains steadily very bright. At that moment the main switch connecting B to the mains is closed. This quite old method of synchronisation suggests the use of the transformer with magnetic fluxes more or less in opposition as in those newer methods for frequency-raising now to be described.

The magnetisation curve of iron is as shown in Fig. 3. When the curve becomes horizontal at P the iron is saturated. If the magnetising current alters on either side of the mean value at I_0 to L or L^1, then in one case we obtain no increase of

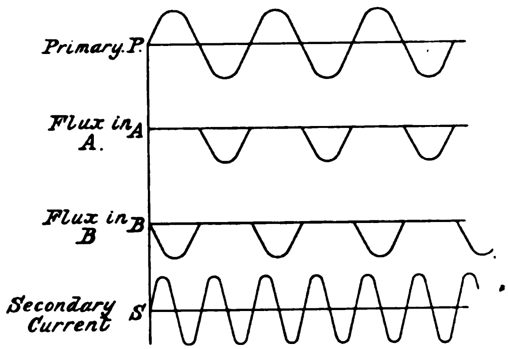


Fig. 5.—Illustrating the operation of the Arco and Meisner frequency raiser.

magnetisation while in the other the magnetisation drops by the value S.

The frequency-raiser of Arco and Meisner operates as follows :—

In Fig. 4 A and B are two transformers, the core of each of these being magnetised

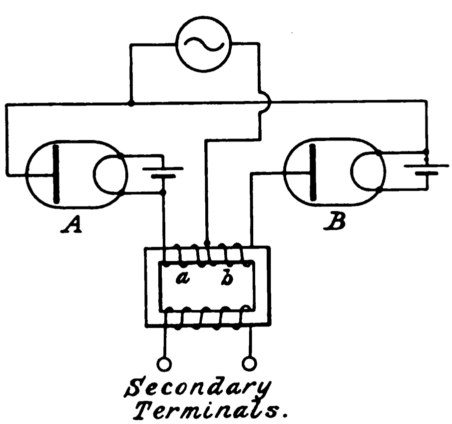


Fig. 6.—Showing the use of diodes for frequency multiplication.

just to saturation by the battery between them. The supplied alternating current passing through the primary of each transformer, in one half wave causes no change of flux, and in the other half wave a decided change of flux. Hence the secondary coil at the bottom of each in the figure has an e.m.f. in it due to this change of flux, the nature of the e.m.f. depending on the rise or fall of the flux.

The two primary windings are wound oppositely to each other and may be either in series or in parallel, while the two secondaries may be connected, either opposing each other or assisting each other. When opposing each other the resulting secondary current has a frequency double that of the primary. When the secondaries assist each other the secondary frequency is three times that of the primary.

Fig. 5 shows the effect graphically, the primary oscillations being shown at P, the flux change in A at A, and that in B at B, while the resulting secondary current of double frequency is shown below.

The soft iron core, when at saturation, is made use of in this ingenious method because of the property it thereby possesses of giving a result when the applied current is in one direction and giving no result when the current is in the opposite direction. Since a valve has unilateral conductivity

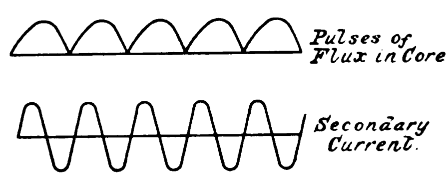


Fig. 7—Illustrating the relation between flux and secondary current.

it suggests itself as another appliance suitable for frequency conversion, and it has been so applied.

The arrangement is shown in Fig. 6 in which a source of alternating current is coupled to two 2-electrode valves. One pole of the supply is connected to the plate of one valve and the filament of the other, and the other pole of supply is connected *vice-versa* through a primary winding of a transformer. The effect is that during one half period the current can flow through the first valve and not through the second, while during the second half period the current flows through the second and not through the first.

Considering the moment when the supply voltage is causing electrons to flow in valve A, then there is no flow in valve B, but it will be seen that the electron current in the transformer coil *a* is to the left. Half a

period later when the electrons are flowing in B but not in A the electron current in the half of the transformer *b* is also to the left. Hence each half period causes a magnetic pulse of the same kind.

Fig. 7 shows the effect of these on the secondary where rising magnetic flux causes a current in one direction, while falling magnetic flux causes the opposite current. Hence the frequency of the secondary current is double that of the primary current. The diagrams of the two methods here given are made as simple as possible, and it should be noted that there are in reality inductances included in the battery circuits to keep the oscillations out of the batteries, and as induced effects are always enhanced in the secondary circuit when this is tuned, in practice the secondary is tuned by inductance and capacity to the required double or treble frequency of the primary current.

A frequency-raiser giving a treble frequency has also been designed by Kujirai.

The principle of the saturated transformer core is used, but he uses three transformers, two only of which are saturated by a battery current. The principle of the apparatus is shown in Fig. 8 in which the primary circuit is the upper line, and the secondary the lower line, the current in this

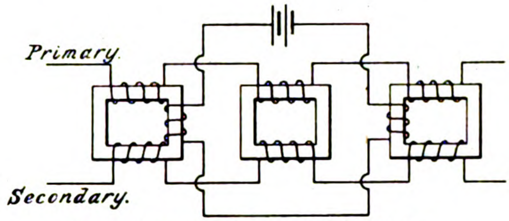


Fig. 8.—A saturated iron core frequency raiser.

latter having three times the frequency of that supplied.

An electrolytic valve as used in various forms for charging accumulators from alternating supply is another unidirectional piece of apparatus which conceivably might be embodied in a form of frequency changer, but the writer is not aware of any method employing this.

Both-way Amplification.

By ALEXANDER J. GAYES.

Although uni-directional amplification is normally employed for most wireless purposes the valve is frequently used so as to amplify from either end of a line. The following summary of the principles employed should provide useful data for experimental work.

THE introduction of one or two stages of L.F. amplification to a circuit carrying speech currents does not present any particular difficulty to the average wireless experimenter. He will arrange his valves, inter-valve transformers or resistance capacity couplings and quickly produce a circuit which will give the desired increase in volume. True, there is more in L.F amplification than is implied by the above remarks, but that is a subject in itself, and it is proposed to consider here, not so much the method of amplifying as the application of amplifiers to ordinary speech circuits.

L.F. amplification as applied to a wireless-receiving circuit is, when all is said and done, only a one-way device. It is a talking channel through which speech can be transmitted from one end only. Imagine a telephone which will "speak" only one way and it will be seen at once how limited is its application. Endless possibilities arise in the application of an amplifier which will function in both directions. That is, an apparatus such that it will give "B" an amplified reproduction of "A's" speech and conversely give "A" an amplified reproduction of "B's" speech. The subject forms an interesting study and gives scope

for experimenting in an application of valve amplifiers which has so far received little or no attention from those outside any direct commercial application such as the introduction of amplifiers in the lines of the Public Telephone Service. Incidentally it should be mentioned that the experimenter must not interfere in any way with the public service: to tamper with, or to attach

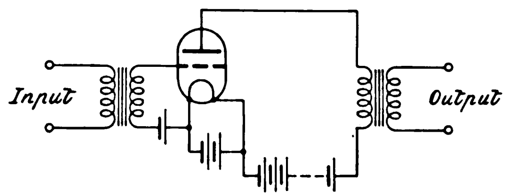


Fig. 1.—The input and output must be independent of external batteries.

to, the public telephone, apparatus of any description is quite illegal, and any mention here of a telephone line refers to a purely private line or the line of a domestic telephone system not associated with the public service. There are many domestic inter-communication schemes, hotel service and the like, where amplified speech might be appreciated. By its aid people with defective hearing could use a telephone. In fact, by the introduction of a both-way amplifier, the improbable but nevertheless possible desire of two partially deaf people to converse over a pair of wires without unduly raising the voice could be accomplished. Loud speakers could be used to replace ordinary telephone receivers, and such apparatus used with microphones in conjunction with both-way amplifiers would give inter-communication facilities over and above those at present at our disposal. Such a scheme might be particularly welcome between patients and nurse, for example, where the former might be quite unable to use the ordinary telephone.

In attempting both-way amplification we are faced with the problem of introducing the amplifier in an existing circuit in such a way as will avoid the magnified output current reacting on the input current. Should any such coupling occur a sustained howl will be the inevitable result. Another point of importance is to so arrange the amplifier as to leave both input and output circuits independent of external batteries. This can easily be accomplished by using a circuit as shown in Fig. 1: the number of valves and the internal arrangement being open to modification so long as the circuits terminate with transformer windings as shown.

Referring now to Fig. 2. If "A" and "B" represent telephone apparatus at two distant points between which amplified inter-communication is desired, it would be possible to insert the amplifier, which we will indicate by a rectangle and designate "C," at a mid-point such that the electrical properties of circuit A, C, simulate those of circuit B, C. With the input terminals bridged across the telephone lines in this manner, it will be seen that a certain portion of the speech currents from either "A" or "B" will pass into the amplifier. This will give rise to amplified output currents which have now to be impressed on the original circuit. A method of doing this is shown in Fig. 3. It will be seen that, broadly speaking, the output energy is divided and a portion applied to circuit A, C, whilst the remainder is applied to circuit C, B. This is a form of bridge circuit, and provided the transformers are correctly connected, and provided also the circuits are electrically balanced, the input circuit of the amplifier will be unaffected by the amplified output current. Consideration of the reverse action will show that the feeble currents from "B" will also be amplified, so we have now the essential and necessary conditions for satisfactory both-way amplification.

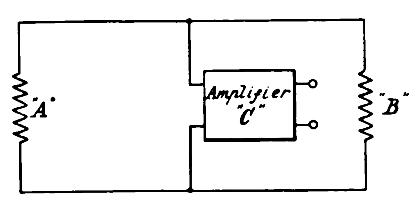


Fig. 2.—Illustrating the fundamental principles involved in two-way amplification.

The successful operation of this circuit depends entirely upon the degree of balance between the "A" and the "B" end. This is clearly shown in Fig. 3, where the dotted arrows are intended to represent the initial speech currents and the ordinary arrows the amplified speech currents. It will be seen that "D" and "E" must be equal and opposite in effect to avoid reaction

and consequent howling. The arrangement is slightly inefficient in that one-half of the degree of amplification is lost, but this is practically unavoidable, and the amplification factor can usually be made such that this loss is of little importance.

In conclusion it should be stated that for such important purposes as the amplification of speech on telephone trunk lines, two amplifiers are used, one working in each direction, and the necessary balance is obtained by means of carefully constructed artificial cables, but that is a telephone problem rather beyond the scope of this article.

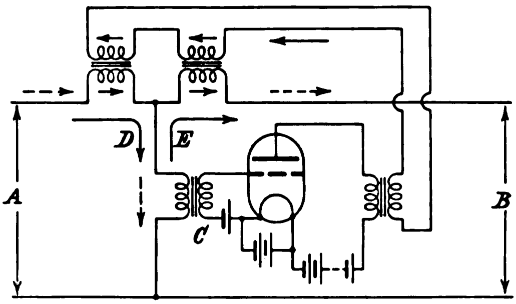


Fig. 3.—A practical amplifier circuit.

Alternating Currents and Wireless.

By Capt. P. P. ECKERSLEY.

It is practically impossible to conduct any serious quantitative investigations without some knowledge of the fundamental principles underlying alternating current calculations. Below will be found a method which reduces the necessary mathematical calculations to little more than simple arithmetic.

IT seems to me that many of us make the mistake of trying to discuss wireless problems without knowing enough of the basic laws. I may, in this journal, be insulting a number of people who live to love pLI and j, but I do hope there may be those among my readers who, though vaguely knowing that "one puts a tuning condenser there," do not quite understand what "resistance" a condenser offers to an alternating current. It is so easy to drop into the jargon, so rare to find one who ever calculates; though never let it be said that I decry the "fool experiment" and would do away with all except calculations.

But a little fundamental knowledge of alternating currents is a useful tool to one who would go a little further than the hobby stage, and as I have, personally, had such intense and awful difficulties in trying to use mathematics, however childish, I have felt that a little article telling of some of the useful hints and tips for use in alternating current work might be useful to many readers.

Wireless problems, thanks to the valve, are, in essence, far simpler than they used to be. The mathematics of the spark, with horrible decrements and logs and so on, was simply hopeless; now it is purely alternating current work, such as can be studied in any text-book on the subject. The frequency only is different—there is no bother about iron and permeability, and often $pL = \frac{1}{pK}$ and one is left with Ohm's law.

If a battery is connected, as in Fig. 1, across a number of resistances R_1, R_2, R_3 a current I will flow. The same current flows through all the resistances. If one wishes to work out the resistance of the whole circuit and calculate the current, one says that—

$$I = \frac{E}{R_1 + R_2 + R_3}$$

This is perfectly childish.

Replace now the resistances R_1, R_2, R_3 by a resistance R_1, an inductance L, and capacity C. Apply now an alternating voltage. The total impedance of the circuit is made of the impedance of the resistance

and the impedance of the inductance and the impedance of the condenser.

Now, the impedance of an inductance is given by pL, where p is 2π times the frequency of the current trying to get through it and L is the inductance. The impedance of the condenser is given by $\frac{1}{pK}$, where p is as above and K is the value of the condenser. This fact can be verified by reference

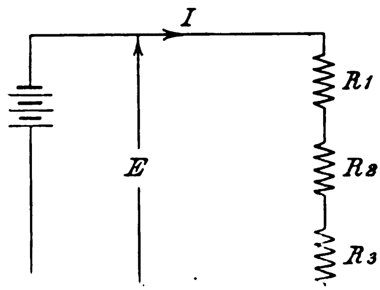


Fig. 1.—The battery E causes a current I to flow through the three resistances.

to various text-books, and it would seem redundant to argue why here.

One might, therefore, say that the total current I that could be pushed from the alternator of Fig. 2 through the circuit was given by the voltage divided by the impedance (or alternating current resistance —Ohm's law). One would then write—

$$I = \frac{E}{R + pL + \frac{1}{pK}}$$

and very simple, but unfortunately wrong.

The voltage produced in an inductance with alternating current flowing through it is a maximum when the current is a minimum (or volts and current are 90° out of phase—and it is a lagging phase); you switch on a voltage suddenly across an inductance—the current does not rise immediately, the current lags behind the voltage; switch on a voltage across a condenser and immediately a current starts flowing, pouring into the tank of the condenser, as it were. The tank does not get full until some while afterwards; the current in the condenser leads the voltage. Thus, again, when the voltage across the condenser is maximum the current is zero in it; always remember, the current leads in a condenser and lags in an inductance. In a resistance, obviously, the currents and volts are in phase. Thus, instead of adding our impedances together arithmetically, we have to add them together vectorially; this is always where so many people get worried.

The thing to do is to get some simple method and stick to it, and I, personally, rather than use anything else, prefer to add the vectors together by the use of j. In Fig. 3, then, from what I have said above, we have three vectors to add together—R resistance, pL inductance, and $\frac{1}{pK}$ condenser. The same current flows in all these parts of the circuit (Fig. 2), and hence we can draw the three vectors as proportional to R, pL, $\frac{1}{pK}$.

It now remains to add them together, and, of course, with a pencil, dividers and so on the eventual vector Z can be drawn, which represents their sum. But how, without recourse to such obvious methods? Suppose, for the sake of argument, instead of writing pL, we write jpL, and instead of $\frac{1}{pK}$ we write $\frac{-j}{pK}$ or $\frac{1}{jpK}$, and we call j the square root of minus 1. Why? I have not the faintest idea. Ask a mathematician. Meanwhile, follow me.

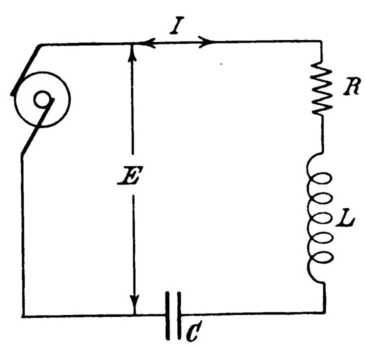


Fig. 2.—How two of the resistances are replaced by a condenser and an inductance.

Now j simply means any vector that is turned at right angles to the vertical line in Fig. 3 in a lagging direction (see the arrow in Fig. 4), and $-j$ or $\frac{1}{j}$ means anything that is turned at right angles in a leading direction. Obviously, terms having j in front of them can be added together arith-

metically, because they are all in the same straight line.

So, in a complicated formula, the obvious thing is to collect all the terms in j together, and add them together arithmetically, and then to take all the terms without j and add them together arithmetically, and write down

$$Z=ja-jc+d-b$$
$$\text{or } Z=j\,(a-c)+(d-b)$$

as an example (Fig. 4).

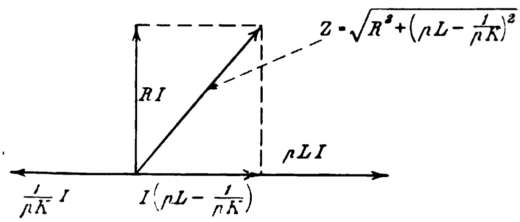


Fig. 3.—A simple alternating current vector diagram.

This means that a and c are all in one straight line, and that d and b are all in one straight line, but the resultant two straight lines $(a—c)$ and $(d—b)$ so formed are at right angles. Obviously, we can now use Pythagoras and vector addition theorem, and say that the sum of the two vectors $(a—c)$ and $(d—b)$ at right angles is—

$$\sqrt{(a-c)^2+(d-b)^2}$$

The imaginary and rather frightening j has disappeared.

Thus the simple rules: collect all terms in j and add them together in one lot; collect all terms without j and add them together in another lot. Forget j, square both the terms that were in j and the terms that were without j, put a square root sign over the lot, and that is the answer.

Never write pL for an impedance of an inductance if you have got to add it to something else Always write jpL. Write: $\frac{-j}{p\text{K}}$ or $\frac{1}{jp\text{K}}$ for a condenser. For all terms in resistances, don't worry about j.

Now turn again to Fig. 2, where the alternator was connected across a resistance, an inductance and a capacity. So as to go very gently, treat them first as pure resistances. You know the voltage of the alternator, but you want to find out how much alternating current you can push through the circuit. If it were D.C. :—

$$\text{I}=\frac{\text{E}}{\text{Total Resistance}}$$
$$=\frac{\text{E}}{\text{R}_1+\text{R}_2+\text{R}_3}$$

but $\text{R}_1=\text{R}$ (the pure D.C. resistance)

$$\text{R}_2=jp\text{L}$$
$$\text{R}_3=\frac{-j}{p\text{K}} \text{ or } \frac{1}{jp\text{K}}$$
$$\text{Then I}=\frac{\text{E}}{\text{R}+jp\text{L}-\frac{j}{p\text{K}}}$$
$$=\frac{\text{E}}{\text{R}+j\left(p\text{L}-\frac{1}{p\text{K}}\right)}$$
$$=\frac{\text{E}}{\sqrt{\text{R}^2+\left(p\text{L}-\frac{1}{p\text{K}}\right)^2}}$$

This is the ordinary Ohm's law for alternating currents, which you probably know already, but I give it to you to show how j helps.

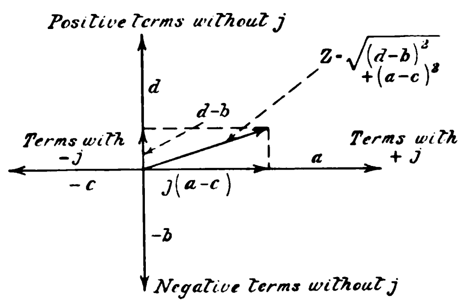


Fig. 4.—Illustrating how the problem could be solved graphically by the aid of a vector diagram drawn to scale.

But before I close I will take one more example, a circuit of Fig. 4. First assume the alternator is D.C. and has a voltage E, and that the three impedances are resistances R_1, R_2, R_3, as marked :—

$$\text{Now I}=\frac{\text{E}}{\text{R}_0}, \text{ where R}_0 \text{ is total resistance.}$$
$$\text{Then } \frac{1}{\text{R}_0}=\frac{1}{\text{R}_1}+\frac{1}{(\text{R}_2+\text{R}_3)}$$
$$=\frac{\text{R}_1+\text{R}_2+\text{R}_3}{\text{R}_1\,(\text{R}_2+\text{R}_3)}$$
$$\therefore\ \text{R}_0=\frac{\text{R}_1\,(\text{R}_2+\text{R}_3)}{\text{R}_1+\text{R}_2+\text{R}_3}$$
$$\text{and I}=\frac{\text{E}(\text{R}_1+\text{R}_2+\text{R}_3)}{\text{R}_1(\text{R}_2+\text{R}_3)}$$

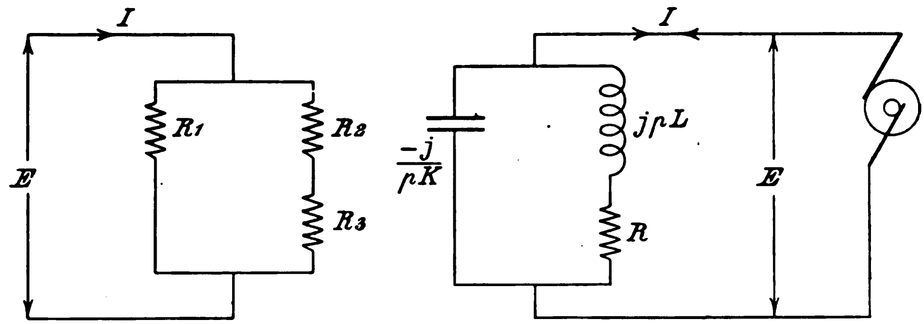


Fig. 5.—Illustrating the similarity between the direct and alternating current circuits.

Turning this into A.C. we have—

$$I=\frac{E\left(\frac{-j}{pK}+jpL+R\right)}{\frac{-j}{pK}(R+jpL)}$$

$$=\frac{pKE\sqrt{R^2+\left(pL-\frac{1}{pK}\right)^2}}{-jR+pL}$$

$$=E\left\{\frac{pK\sqrt{R^2+\left(pL-\frac{1}{pK}\right)^2}}{\sqrt{R^2+p^2L^2}}\right\}$$

(Note if $pL=\frac{1}{pK}$ and $pL>R$

$$\frac{\sqrt{R^2+p^2L^2}}{\sqrt{R^2+\left(pL-\frac{1}{pK}\right)^2}}$$ is the impedance)

$$\text{Then } I=\frac{ERpK}{pL}$$

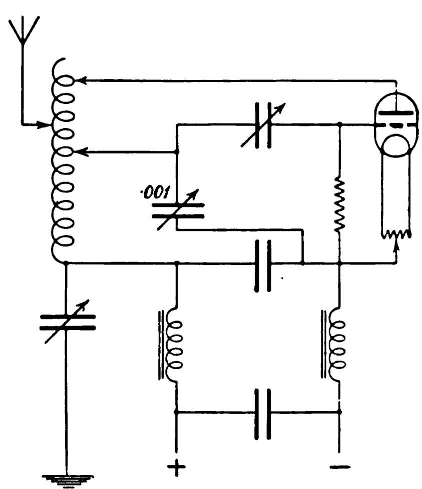
$$=\frac{ER}{p^2L^2}$$

This is the case where the circuit is in resonance, or the impedance of the circuit is—

$$\frac{p^2L^2}{R}$$

Experimental Station oMX.

In the November issue of EXPERIMENTAL WIRELESS there appeared an article entitled "Amateur Radio Work in Holland," by J. Westerhoud. Many details of apparatus and circuits employed by Dutch experimenters were given, including that used by oMX. As considerable interest has been aroused, and also some little confusion, we are reproducing a diagram of the actual circuit employed, which, it will be noticed, is of a rather peculiar type.



Circuit used by OMX.

The "Old Vic" Wireless Relay.

By A. G. D. WEST, B.A. B.Sc., Assistant Chief Engineer B.B.C.

In the last issue of "Experimental Wireless," details were given of the system used for land line connection of microphone to transmitter. When this is impracticable a relay transmitter is used as described below.

ALTHOUGH the relaying of music by wireless for transmission appears quite simple in principle (as shown in Fig. 1) many difficulties cropped up when this method was first attempted and in this article I propose to deal with some of the special problems connected with this kind of work.

The aim is to produce for the operation of the control valves of the broadcasting station a replica in tone value and balance of the original music, without any loss of quality; are used for a distance greater than three or four miles a loss of quality is apparent, because, owing to the large capacity between the two wires of the system, the higher tones do not get through relatively so well as the lower tones, and it is the higher frequencies that give to music its essential qualities.

Although it is under a mile from the "Old Vic" Theatre to Savoy Hill, it was found to be impossible to provide a direct landline connecting the two, and the best that could be supplied was a line (underground of course)

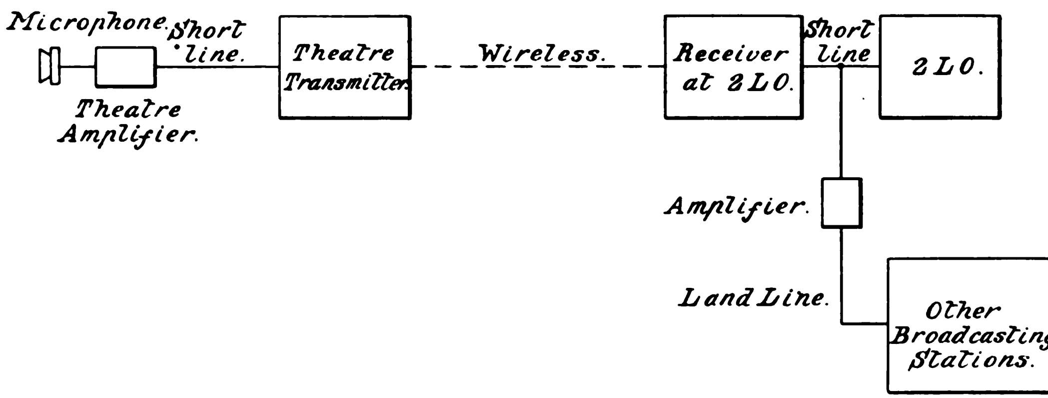


Fig. 1.—Schematic representation of system used in wireless relay.

and in the case of the broadcasting of opera there are intrinsic difficulties of maintaining a correct balance between the orchestra which is fixed and the artistes who are always moving about, and of keeping the average strength of music arriving at the broadcasting transmitter between the limits which determine its efficient operation.

It is well known that for the transmission of music along ordinary telephone lines, these lines must be capable of carrying low-frequency currents of between 30 and 8,000 cycles a second with equal efficiency to retain the original quality of the music. Overhead wires of considerable length satisfy this condition, but when underground wires of some seven miles in length. Hence the original reason for the attempt at a wireless link.

The chief technical difficulties to overcome were as follows. First of all a suitable transmitter had to be designed to suit the conditions of theatre work; one that would deal effectively with the weakest and the strongest sounds without loss of quality and that would bring them all to much the same level. Secondly, in receiving the transmission from the theatre to the London Station all possibility of interference from the latter must be avoided. Thirdly, in passing through the whole series of valves from the microphone to the London transmitter, special

precautions must be taken against distortion which might not be apparent if the chain consisted of a few transformations, but which only too easily exists when a large number of steps of valve magnification are employed. The following description will show how these difficulties were overcome.

Transmitter.

The standard type of theatre microphone was used and placed on the front edge of the stage in the centre, the place which has generally proved to be most effective for the transmission of operas and giving the best balance. The currents through the microphone after being magnified by a two-valve low-frequency transformer amplifier at the back of the stage are of sufficient strength to control the transmitter which is situated in the building next door. It is in this amplifier that the strength of the music is controlled by a grid potentiometer and is kept within the proper limits. It is a very difficult matter to do this well; an artiste may turn away or move to the back of the stage, and whereas a listener in the audience would notice no difference in volume of sound on account of the adaptability of his ears and of his nearly equal difference from all parts of the stage the microphone only deals with what it gets: lack of strength must be made up for in the stage amplifier and movements on the stage must be if possible anticipated.

At the last valve of this amplifier the potential is transformed down on to the line to the transmitter, and then up again to operate the grid of the subcontrol valve which is a 50-watt valve and in turn feeds the control valves (200-watt valve) the connection being by the usual resistance capacity method. These large valves are specially chosen so that with suitable negative grid potentials we operate on the straight parts of their characteristics. Furthermore, sensitive galvanometers are placed in series with the grids of control and subcontrol valves to indicate the existence of grid current; and the engineer in charge operates a variable shunt across the line from the theatre by means of which he reduces the strength entering the transmitter if there is any likelihood of grid current. The oscillator valve is a 50-watt valve, very much under loaded.

Such a transmitter may appear very uneconomical, but the choke control method always has the advantage that with suitable instruments we know "where we are." For low-powered sets where economy is the chief consideration and quality comes second the grid method of control is very effective, provided that stable conditions exist in the high-frequency circuits, but in this set quality is the first consideration, so choke control is used. Another point that is of the utmost importance in low-powered circuits is the efficiency of the aerial-earth circuit, especially when working on very short waves. The difficulty of finding a suitable earth connection in the top story of the building necessitated the use of a coupled circuit and

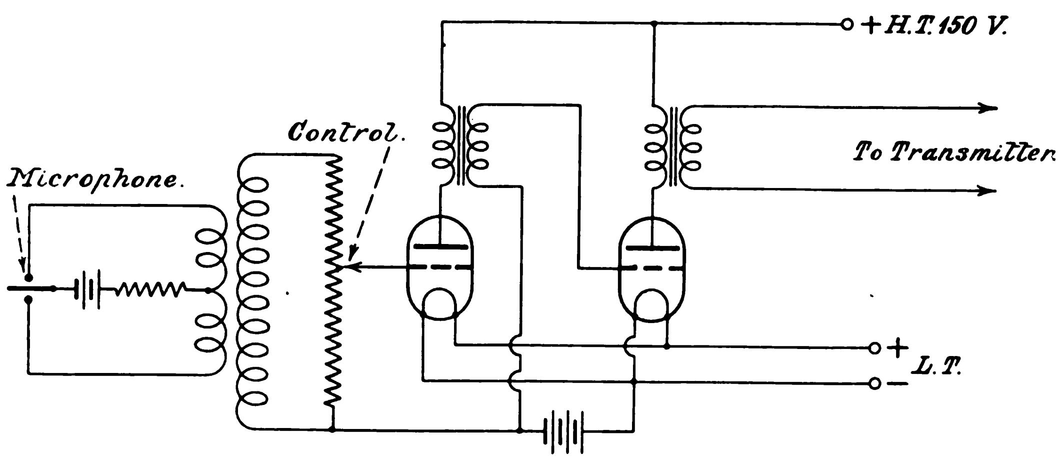


Fig. 2.—Theatre microphone and amplifier circuits.

earth screen, and there is no doubt that when short waves are used this method is generally the best. Again it is a case of knowing "where we are" as regards tuning. All the circuits can be buzzed seperately and some idea obtained of the number of turns required on each coil. On short wave-lengths with doubtful earth connections auto-coupling is sometimes difficult to manage. With regard to modulation in this particular transmitter as a result of all the precautions taken to ensure no "blasting" in any circuit at maximum strength of music from the theatre, it can be understood that the modulation is really very small, probably averaging out at about a tenth of the maximum. With regard to aerial, this is a single wire about 25 feet long and 20 feet above the roof of the house. This type is in many respects more satisfactory than any other for telephony on low wave-lengths.

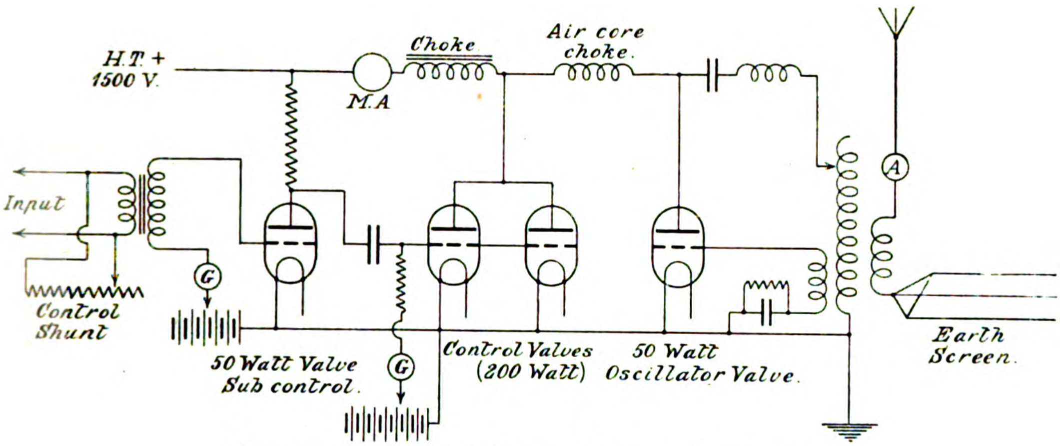


Fig. 3.—The actual choke control circuit used for the theatre transmission.

The transmitter is, except for the aerial and earth screen, quite self-contained, the generator and filaments being all run off accumulators.

The Receiver at 2LO.

To ensure sensitivity and selectivity, and freedom from interference from the London transmitter, a super-heterodyne receiver is used with a small single-wire aerial. For short wave-lengths the super-heterodyne receiver certainly has no equal as it offers three distinct methods of magnification—original high-frequency, beat-note and low-frequency—and the combination of these three is extremely effective. Usually sufficient sensitivity is obtained without the first, connecting the aerial circuit direct on to the first detector valve. This receiver is just as remarkable from the point of view of selectivity, and immunity from interference by near-by stations when it is properly designed. It is important to get the strength of the heterodyne right for best results, the easiest way of doing this being to use a variable coupling with the closed circuit of the receiver. If it is required to cut out a near station working on a wave-length of reception, a power valve must be used closely coupled to the receiver. Care must be taken when receiving telephony that if necessary sufficient damping is introduced so that the higher speech frequencies are not cut out, thus giving distortion. This can be done by using a suitable transformer, wound to the beat note wave-length, in the anode circuit of the first detector valve and the beat-note amplifier must be kept well under control and right off the point of oscillation. Any of the usual forms of high and low-frequency magnification may be used in this circuit. In the particular receiver we are considering resistance capacity coupling is used for both high-frequency and low-frequency amplification, and in the latter there is no distortion if the resistances and capacities have correct values and it is ensured that no grid current flows by using

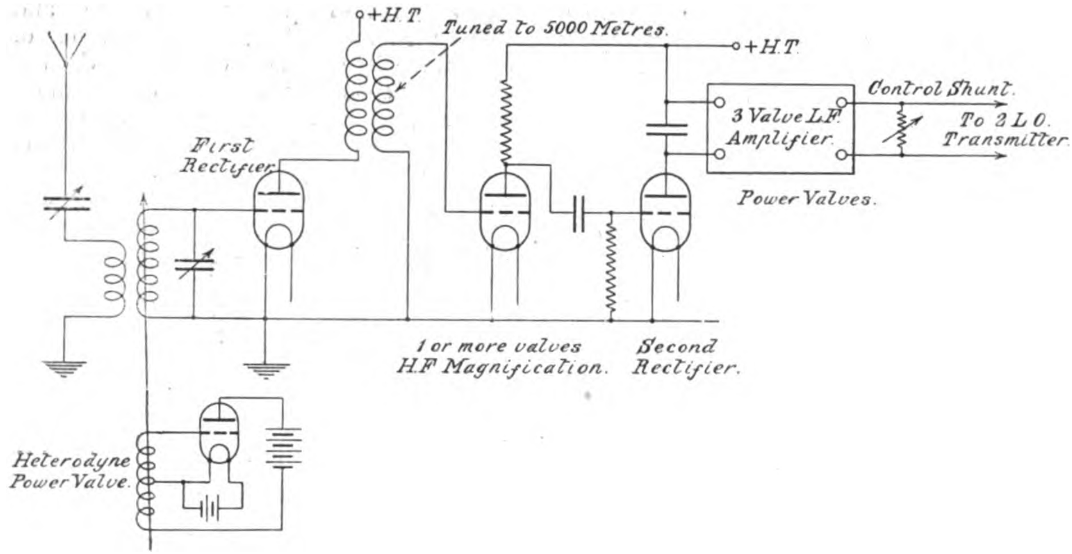


Fig. 4.—The supersonic receiver and amplifier which is coupled to the 2LO transmitter.

sufficient high tension, and negative potential on the grids for the valves in use.

It is best to screen the beat-note frequency amplifier with copper foil which is earthed, as it very easily picks up carrier waves and harmonics of commercial stations. The music is thus received and brought up to sufficient strength to operate the London transmitter and if necessary the transmitters of the other stations through the amplifiers controlling the various simultaneous lines. The various units in the photograph of the receiver, reading from left to right, are as follows: heterodyne with fine adjustment, aerial and closed circuit condensers, first detector valve, screened transformer, beat-note amplifier, low-frequency amplifier, controlling potentiometer.

So much for the apparatus actually in use for the wireless link, but there are still many minor difficulties which still await solution.

Although the London Station has been eliminated in the receiver, now and then a harmonic of a C.W. station or the oscillation of a neighbouring receiver is picked up and sometimes noticeable in a weak part of the music. Generally these can be tuned out by adjusting the heterodyne without affecting the reception from the theatre. Sometimes faint interference is experienced from an electric motor or a lift in another building and this is only to be expected when using a sensitive receiver in the heart of London. So far such interference is not really serious, but when the wireless link is extended up to a distance of ten miles or more it will be a difficult matter to keep the reception pure and free from interference and atmospherics without a corresponding increase of power in the transmitter. An interesting fact is the absorption of certain very short waves in passing over London. On one low wave-length tried for this wireless link of only a mile, very poor results were obtained, while a slightly higher wave-length was much more successful; and while picking and choosing among wave-lengths it is, of course, necessary to steer clear of harmonics of 2LO.

In extending this wireless form of relaying up to a large distance, there is no doubt that much greater difficulties will be experienced, but it is hoped that these will be overcome in time, so that the transmitter can be made a portable one (that is installed in a car) and then this method will be available for the broadcasting of any form of programme from anywhere in the London district at more or less a moment's notice.

Notes on Sources of Energy Loss in Condensers.—II.

By PHILIP R. COURSEY, B.Sc., F.Inst.P., A.M.I.E.E.

THE possible sources of energy loss in condensers which we have so far been considering should in any well-constructed condenser represent only an almost negligible amount of energy. There are, however, many other uses to which condensers can be put other than those mentioned, and in some of them not only are there more possible sources of loss, but the order of magnitude of these losses may be much greater. These additional losses will often be added to whatever loss may exist of the types that have already been discussed.

For example, consider a condenser connected to an A.C. circuit so that it is subjected to a high alternating voltage of low frequency, such as 50 cycles.

There will, in the first place, be a direct breakage of current through and over the surface of the dielectric. This loss will not be a constant one, but will vary both with the frequency of the A.C. and with the voltage applied to the condenser, as has already been indicated. This A.C. leakage—the "leak-over" of the telephone engineer —may frequently be much greater than might be

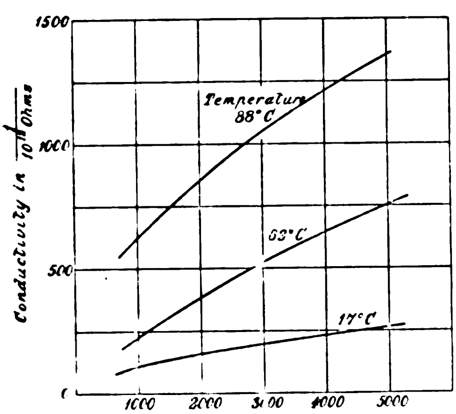


Fig. 1.—Leakance through glass at different temperatures.

anticipated from the D.C. tests on the dielectric in question. Some idea of the increase may be gathered from Fig. 1 which is typical of the type of result obtainable when the tests are made at telephonic frequencies. From such tests as these one is led to the conclusion that the leakage loss in watts may become, in a condenser subjected to an A.C. voltage, a loss which it is of importance to consider. It is of interest also to note that the loss increases with the temperature of the dielectric.

In the second place we have an actual energy loss in the dielectric, consequent upon the alternating electrical stress to which it is subjected—this loss being usually

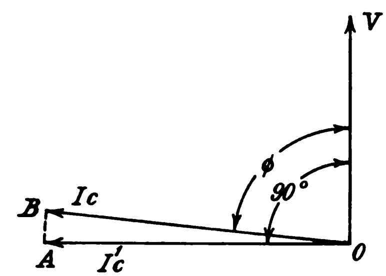


Fig. 2.—Vector diagram showing effect of losses.

attributed to dielectric hysteresis. And in the third place we may have an augmented loss due to the formation of corona or "brushing" where the voltage on the condenser is at all high.

These three sources of loss are, generally, in the case of a condenser subjected to an A.C. voltage, summed up in the quantity known as the "power-factor" of the condenser. The normal "capacity-current," which glows through a condenser of capacity C microfarads when it is subjected to a sine-wave alternating voltage of V volts at a frequency of f cycles per second is

$$I_c^v = \frac{2\pi C f V}{10^6} \text{ amperes.}$$

If the condenser is a perfect one this current I_c^v will be 90° out of phase, with the voltage V as sketched in Fig. 8, but in actual practice there must be some losses, although these may, and should, be very small. The actual current which passes through the condenser should therefore not be represented by the

vector OA but by the vector OB, which is marked I_c in Fig. 8, making an angle ϕ with OV, ϕ being slightly less than 90°. The power-factor of the condenser is the same given to the quantity numerically expressed by the cosine of the angle between OB and OV, *i.e.*, by cos ϕ. It is, therefore, the ratio of the lengths of the vectors AB and OB.

This ratio expresses the ratio of the power-expended in the condenser, *i.e.*, the energy losses—to the apparent, or wattless power, in the circuit. Numerically, if W is this energy loss, the power-factor is expressed by

$$\frac{W}{I_c V} = \frac{I_c^2 R}{I_c V} = \frac{I_c{}^2 R}{I_c{}^2/(2\pi c f)}$$
$$= 2\pi R C f$$

This relation is only true when the losses are small. In this expression R is the effective resistance of the condenser, which is the resistance value in ohms which expresses the loss in the condenser. It is a quantity that can often be measured directly by certain capacity measuring bridges, but is only determinable with ease at audio frequencies. The relative size of the "loss vector" AB

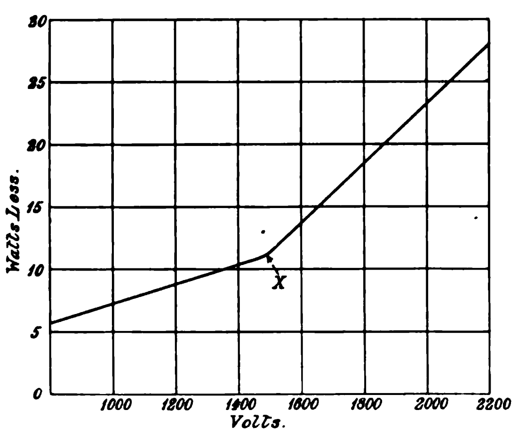


Fig. 8.—Curve of energy loss as function of voltage on condenser.

in Fig. 8 has been much exaggerated, as in a good condenser its length is a very minute fraction of the lengths of the other vectors. It is this fact which renders its measurement difficult.

The power factor of a condenser having a solid dielectric should be quite a small quantity (less than one-tenth of one per cent.) when measured at audio frequencies,

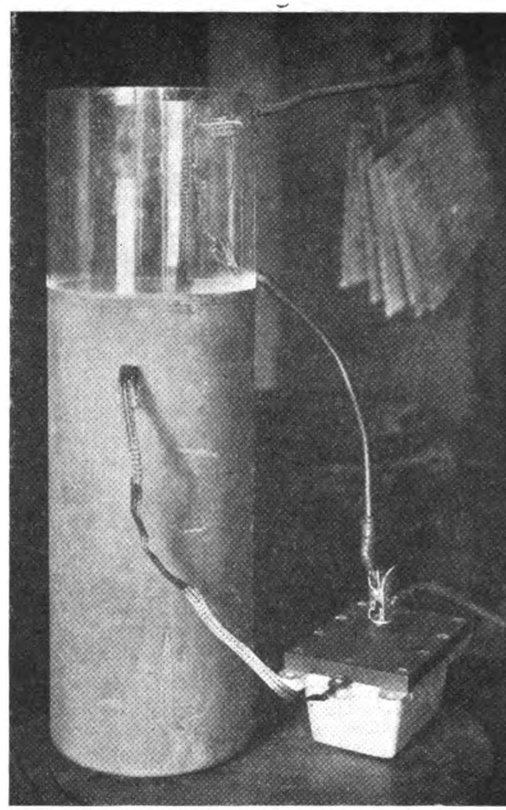


Fig. 4.—Brush discharge on glass dielectric condenser.

with only a low voltage on the condenser terminals, but the production of a condenser that will have an equally low power factor when operating in a high voltage radio frequency circuit is not a particularly easy matter. There are many reasons for this difference between the results obtainable at low audio frequency voltages and those at high voltage radio frequencies. In the first place, the loss due to dielectric hysteresis increases usually very rapidly with the frequency, while, secondly, the extra losses due to corona, which are non-existent at low voltages, become serious at high voltages, and especially so at high radio frequencies. Measurements of energy loss in condensers, as the voltage on the condenser is raised, show up the effect—Fig. 9. It will be seen that there is almost a discontinuity at the point X in the curve of watts loss, this point marking the formation of corona, or a brush discharge at

the electrodes of the condenser. Energy loss, due apparently to this cause, may actually begin before there is any visible sign of corona on the plates—the loss being probably due to the generation of a number of extremely minute discharges. Once visible corona commences, however, the loss may become very serious and lead to a rapid heating up of the whole condenser.

A well known example of the effects of brushing at the edges of a condenser plate is provided by the glass plate condensers commonly used as part of a ship's radio installation. If one of these condensers is examined after it has been in operation for some time, there will frequently be found a distinct groove in the surface of the glass sheet corresponding with the edge of the condenser plate which has been in contact with the glass. This groove is entirely due to the brushing that has taken place off the edge of the metal, the brush discharge gradually melting its way into the material of the dielectric. This brushing takes place in these condensers, even although they are operating on a spark transmitter, but the effects would be much worse if the condenser were in a circuit. A brush discharge from the edge of the metal electrode will gradually spread into the material of the dielectric until an actual puncture occurs.

The old fashioned Leyden-jar type of condenser showed the same efiect—Fig. 4—and consequently often broke down for this reason. The photograph shows a Leyden jar subjected to the same test voltage as a small mica dielectric condenser, of the same capacity, and illustrates the brushing taking place round the edge of the metal coating of the jar, while no such luminosity is to be seen on the mica condenser.

This brushing, or corona, brings about considerable heating of the dielectric, as is emphasised by the curves in Fig. 5, which show the energy losses for a Leyden jar and for a mica condenser, both condensers having a capacity of 0.004 microfarad. The rapid increase of loss with rise of voltage should be noted.

Losses of this type are by no means entirely confined to condensers having a solid dielectric, and although it is frequently stated rare air, is a perfect dielectric and that therefore an air condenser cannot have any losses, such is in practice far from being the case. Even a variable air condenser used in quite low voltage radio frequency circuits may have in it appreciable energy losses, due apparently to the excessive value of the electric stress in the air. Some of the variable air condensers having extremely close plate spacings are bad in this respect, and even when subjected to a radio-frequency voltage of 20-30 volts only may have a loss resistance of several ohms introduced by this cause. When the radio-frequency voltage is high an air condenser may have a considerable loss. Under these conditions a condenser properly designed for operating on high C.W. voltages, with a good solid dielectric such as mica (Fig. 6), may be superior to an air condenser in this respect, besides being much smaller in

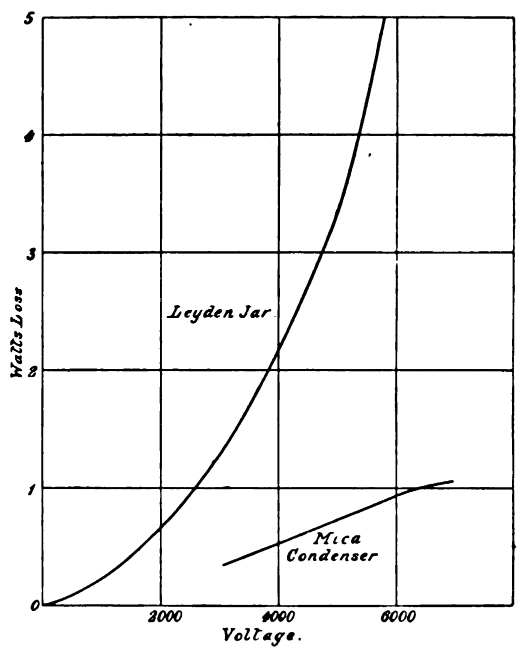
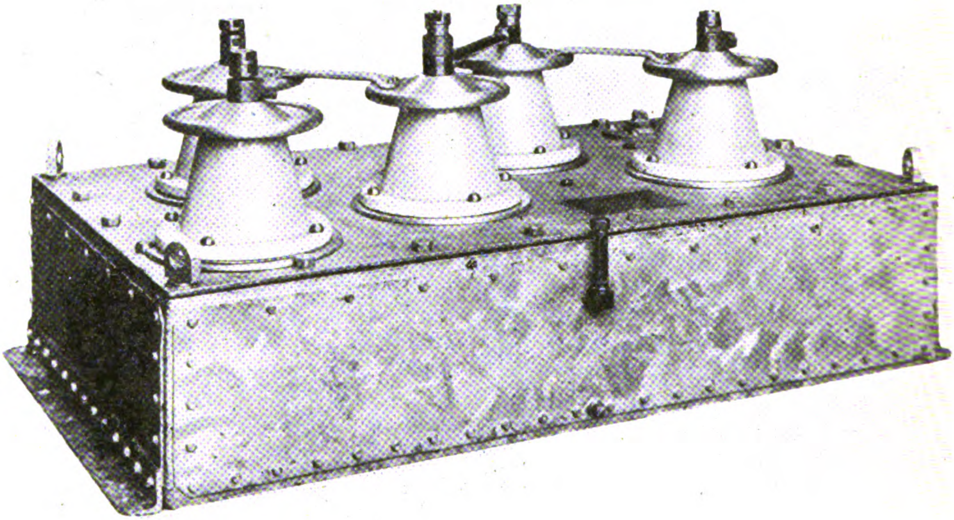


Fig. 5.—Energy loss in glass and mica condensers.

bulk. For instance, the power factor of the condenser illustrated in Fig. 6, which has a mica dielectric, is only of the order of 0.00006. This result has only been obtained through many years of research in the methods of manufacture of such condensers.

The small value of the power factor possible in such condensers emphasises the freedom from corona effect and other similar



F. 6.—A modern mica condenser for operation on high radio frequency voltages. [By courtesy of Dubilier Condenser Co., Ltd.]

sources of loss, as the large radio-frequency voltages to which these condensers are subjected so readily give rise to such losses, especially at the short wave lengths where the frequency is high and the currents also large.

Anyone who has experimented with the use of dielectrics in intense radio-frequency fields cannot fail to have been impressed with the extraordinary heating effects to which such fields can give rise. Quite large masses of dielectric can be heated up by the application of a high radio-frequency voltage for a few moments only, if the shape of the dielectric and the mode of application of the electric field to it are unsuitable. These effects accentuate the difficulty of leading the current into and out of the condenser, unless the terminal insulators are suitable. It is easy to have a greater loss in the terminal insulators than in the condenser itself, if they are improperly designed for radio frequencies. These losses are more due to the so-called dielectric hysteresis than to corona effects.

Apart, altogether, fron the disadvantage of the existence of losses in a condenser from the point of view of the energy wastage involved, and the possible augmented cooling means which may be necessary to dissipate this energy wastage, there is the more serious side of the matter due to the fact that most dielectrics become weaker as their temperature is raised. Referring again to Fig. 1, it will be noted that the leakage loss increases with the temperature of the dielectric. All other dielectric losses usually similarly increase with the temperature, so that an initial energy loss in the condenser which causes a rise of temperature may as a consequence bring about an increased rate of energy loss, due to the effect of temperature rise on the dielectric losses, and consequently a further temperature rise results. This effect may in a poor condenser ultimately cause a breakdown of the dielectric, but should not occur in a well-designed one.

These few notes on the different types of energy loss which may occur in a condenser may serve to emphasise the great difference between the problems encountered to-day in producing an efficient condenser for operating in C.W. circuits, from those met in condensers for spark, or "damped wave," transmitters. It is perhaps not too much to say that the revolution that has been brought about in radio frequency condenser design by the extended use of continuous waves radio transmitters is hardly less than that caused by the introduction of the thermionic valve into the radio receiver.

The Month's "DX."

Recorded by HUGH N. RYAN (5BV).

The increasing efficiency of amateur transmitters and receivers is resulting in the creation of many new long-distance records which are undoubtedly worthy of mention. It is proposed to record month by month work in this direction, and the Editor will be pleased to receive details for inclusion in these pages.

SINCE last month's notes the DX world has awakened well and truly. Last month the all-night listener for Americans heard nothing but Americans and a few hetrodynes (the number of Americans logged varying inversely as the umpteenth power of the number of hetrodynes.)

Now, however, most of the long-awaited high-power transmitters are in action, and, judging by the awful row that goes on in the small hours, the power really is high.

The time for producing long lists of "Yanks heard" is past, and everyone is striving to be the first to "get over" or, better still, accomplish two-way working with the States.

Since there are few very good logs this month, I will deal with the few first. The fact that anyone can get so many Yanks through the QRM shows that conditions are splendid. The small number of logs is due entirely to the fact that most of the best men are engaged chiefly in transmitting. By far the best night yet was that of December 1-2. Conditions on that night were not very good until about 6.50 a.m. on the 2nd, when Americans started to come in as fast as they could be logged, and were still coming in at 8 a.m. in broad daylight!

Between 7 a.m and 8 a.m. 2AAH logged twenty-six complete calls (*i.e.*, call-sign of both calling and called stations), as well as many other single call-signs logged, on one valve—a very fine performance. On the same morning, between 6 a.m. and 8 a.m., 6LJ, another London man, logged thirty-seven Americans, calls being received from every district except the seventh—another excellent piece of work.

Mr. Rogers, a receiving man at Ashford, has logged some fifty Americans on one and two valves.

No reports from the north are to hand.

The excellent conditions indicated by these results give us great hopes for the official tests in the near future.

On that splendid morning, December 2, I answered a CQ from 8AJW, and received a reply asking for a repetition of call-sign and more power. Unfortunately, the rest of the working was spoilt by a humorist with a hetrodyne who appeared to think that his call-sign was 8AJW!

The reception of PCII by 7ACM, reported in last month's notes, was, unfortunately, not true, being due to a similar hetrodyne masquerading as 7ACM. It is most unsporting behaviour on the part of the stations who do this sort of thing with their hetrodynes, and it is to be hoped that they will have the decency to refrain from it in future. In this case, PCII has our entire sympathy, and we wish him all the better luck in the near future.

8AB, of Nice, whose 25-cycle note was so familiar last year, has been in America ever since the end of last year's tests, and has only just returned. Not many people have noticed his return, however, as he now works on 130 metres! He has already worked with two American amateurs, who appear to get him very well on that short wave-length.

Many of the Americans are also down on that wave, and come in very loudly indeed. The great advantage of going down there is that horrible fading which characterises all 200 metre work is almost entirely absent. After being used to the effect, it sounds quite uncanny to hear a weak distant station staying at a constant strength. Low power signals also seem to carry very well indeed on this wave-length. I think that by the time we are working regularly with the States (and may it be soon), it will be on about 150 metres. It promises to be the

wave-length for DX as soon as the majority of stations can receive it efficiently.

That practically completes the American news.

The R.S.G.B. station, 5AT, is now going strong. It has sent out some very useful calibration waves, for the benefit of the many who do not quite know where 200 metres is, and the knowledge of the exact position of this and the other waves sent will be of great benefit to many who do not possess wave meters.

Also 5AT has recently been working in the small hours trying, like the rest of us, to "get over the Pond." He has also been calling the elusive WNP, but with, unfortunately, no more success than we have had.

We have this month had the unusual experience of hearing our friends the broadcasters engaged in perfectly good DX. The tests have been so widely reported in the technical press, that no more than a passing mention is necessary here. Nevertheless, we congratulate them upon their temporary entry into our nocturnal activities. (By the way, we know now what Uncle Arthur means by "The night shall be filled with music!")

The tests showed, at any rate, that the B.B.C. are no more immune than we are from the spells of bad conditions which always come when they are least wanted.

European DX has rather been overshadowed by the American work, but several interesting results have been obtained.

On December 4 signals from 6DW of London were received at good strength by 5US of Yorkshire, on a 4-foot frame and single-valve super. The input at 6DW was about 2 watts, and aerial current ·13 amps. The distance between 6DW and 5US is approximately 190 miles.

5DN of Sheffield, whose call-sign is familiar to many London amateurs, has been heard in Switzerland. He was using 10 watts, and his aerial current was ·42 amps. This is an interesting example of what can be done with a small aerial current, as even though ·45 is not a good aerial current for 10 watts, it travels as well as the ampere obtained by some stations more technically "efficient."

Mr. F. R. Neill, of Belfast, has contributed greatly to the interest of DX recently by his excellent reception of many English stations. His usual receiver comprises 1HF and 1LF stages, and on that, for example, he can read my own signals all over the room.

I believe he has received very good telephony from 2OD. It would be interesting to know if there is a place where 2OD's telephony cannot be heard. His transmission is extraordinarily good, and seems to carry everywhere.

On December 9, between 2 a.m. and 3 a.m., 2AAH and myself received KDKA (Pittsburg Broadcast) very loudly indeed on approximately 100 metres. It seems impossible that this could have been a harmonic, especially as the fundamental was very weak indeed that night. It also appears impossible that it could have been a retransmission from a station in this country, as the music and speech was absolutely pure, and seemed quite evidently a first-hand transmission. Also, it was not fading in the least, as was the fundamental, so it could not have been picked up on a super-receiver and retransmitted.

KDKA was probably experimenting with transmission on two wave-lengths simultaneously, as I believe several American stations have been doing recently. Single-valve receivers were used in both cases.

The new "A" code of signal strengths published in these notes last month has "caught on" to some extent already. I have heard it used several times by DX stations, and at least one station has had the code incorporated in his printed report cards.

A number of experimenters have approved of the code, and asked me to "boost" it further, so let's hear it used more!

Just before going to press comes the great news that 2KF has, on several consecutive nights, worked with American 1MO. The results are fully authenticated, and 2KF has our heartiest congratulations. The wave-length used by 2KF was very low, as was his power (aerial current being under 2 amps.)

This achievement has just been followed up by some excellent work by 2SH who has for several hours established two-way communication with 1MO, 2AGB and Canadian 3BP, which it is understood is located in Ontario. 2SH has also been reported by 5XD of New Mexico, about 600 miles from the Pacific.

The Construction of a Tuned Reed Rectifier for 200-volt 50-cycle Supply.

By E. J. SIMMONDS.

One of the most useful methods of rectifying alternating current is by means of the vibrating reed. The success of the apparatus is dependent upon correct design and adjustment, details of which are given below.

THE following article describes the construction of a simple but efficient type of tuned reed rectifier for accumulator charging from A.C. mains. The instrument is built on well known-lines, but with the addition of several adjustments, which increase the flexibility and control. It consists broadly of a step-down transformer, rectifier panel, with steel reed, permanent magnet, exciting coil and potentiometer.

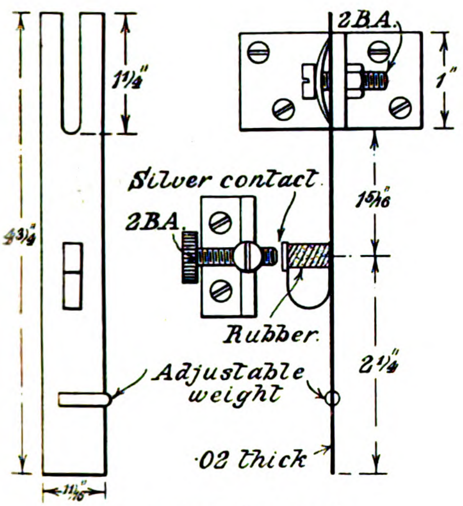


Fig. 1.—Details of tuned reed.

This rectifier can safely be left to recharge the cells overnight up to a 5-amp. rate, and has been in use at the writer's station for two years, giving every satisfaction; also the first cost is very low.

The most important point is undoubtedly the tuned reed, and care should be taken to adhere to the dimensions given, which are the result of much experiment. The reed is a strip of spring steel 11-16th" wide ·02" thick and 4¾" long. This may be conveniently obtained from a broken gramophone spring (the springs of H.M.V. machines are of correct thickness). If a piece of this spring

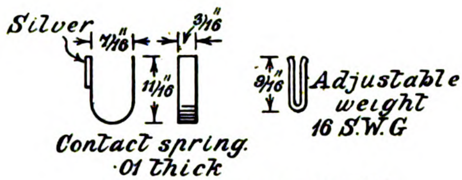


Fig. 2.—Details of spring and weight.

is used it will be too wide, but can be reduced to correct dimensions by gripping in a vice with the unused part protruding. If this is now firmly held by a pair of pincers it can readily be torn off. The resulting rough edge should be ground smooth on a carborundum wheel or stone. The steel could of course be softened and cut in the usual way, but the process of rehardening and tempering requires considerable skill. By my

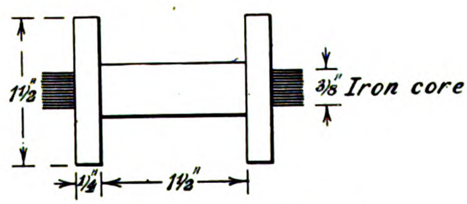


Fig. 3.—Dimensions of exciting coil.

method the original temper of the steel is preserved.

The next point to which attention is directed is the U-shaped contact spring.

The alarm spring from the average drum clock will be suitable, the actual dimensions are thickness ·01" width 3-16th". This is

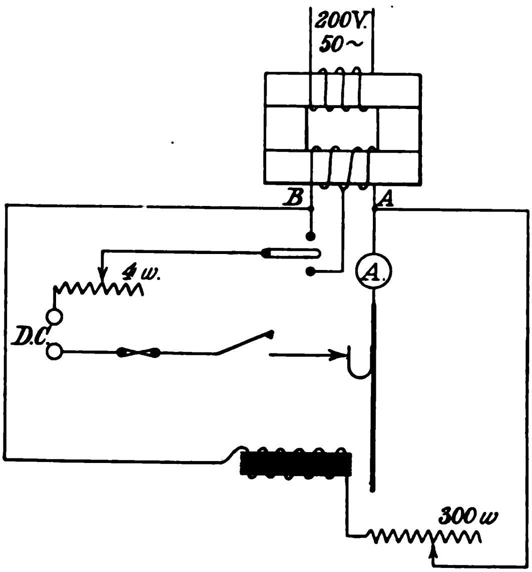


Fig. 4.—The connections of the rectifier.

soldered in position indicated on the reed. Here will be noticed an unusual arrangement.

This spring is effectually damped by a column of soft rubber, with its base fixed to reed. In practice, the effect of this damping is to render the instrument more accomodating to irregularities in the wave-form of the power supply. Considerable difficulties were encountered in the early experiments with the rectifier, until this simple damping

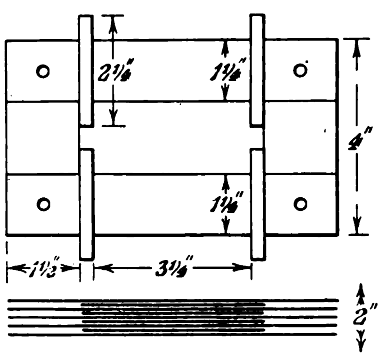


Fig. 5.—Details of transformer coil.

device was added. Soft indiarubber as used for erasing will be found excellent for this purpose. It should be noted that a spiral spring would not be suitable, as it would have its own natural period.

The contacts on both U-shaped spring and contact screw are of silver, soldered in position. Tungsten may of course be used, but is quite unnecessary.

After about 100 hours use at 3-4 amp. rate the contacts may be trimmed up with a dead smooth file. Another useful addition is the small sliding weight on the reed. By this means accommodation may be obtained for temperature changes, and also slight fluctuations in the frequency of the supply. This weight is made of spring brass or steel wire, about 16 S.W.G., bent to shape as shown, and should grip reed tightly, although capable of being slid up or down. The dimensions of the permanent magnet are not critical; one from an old magneto will be suitable.

The exciting coil consists of a former

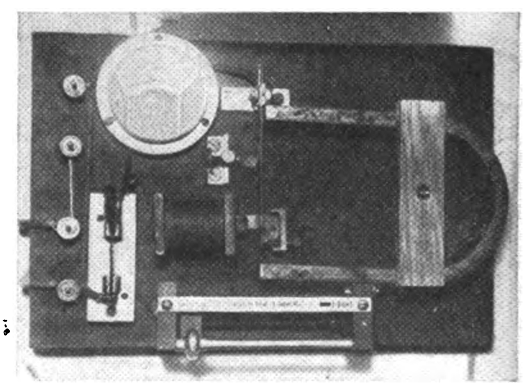


Fig. 6.—A general view of the rectifier with switchgear.

2×1½×1½" layer wound full of 30 D.S.C. copper wire. The core is a bundle of soft iron wires, and made a nice sliding fit in the tube to allow for final adjustment. It will be noticed that in series with this coil is a potentiometer of 300 ohms. By suitable adjustment of the slider the reed may be arranged to break contact when the E.M.F. of charging current is at any required value between 2 volts and 10 volts.

It is of course clear that to obtain sparkless operation the contact must be opened when the E.M.F. of charging current equals the opposing voltage of the cells on charge; at that moment no current will be passing at the contact.

The potentiometer control gives a ready means of obtaining the critical adjustment, without any alteration of contact screw,

and is a most important point in the successful operation of the rectifier. When charging a 10-volt battery practically all the resistance will be included in the circuit; more and more resistance will be cut out when charging cells of less voltage.

Several points of importance should be noted in the bracket support for the reed. This is made from two pieces of angle brass ⅃ L, sweated together, and is firmly screwed to the hardwood base. The reed is clamped by a clamping plate and 2-B.A. screw and nut. It should be observed that the small clamping plate is slightly curved, the concave face being placed next to reed, and it is important that the lower edge of the clamping plate, and also the edge of the bracket, plete the magnetic circuit. The two limbs carrying the primary and secondary are made up from alternate long and short sections, and the cheeks which are of vulcanised fibre are then attached.

The core is carefully insulated with empire cloth or thin vulcanised fibre, and the primary and secondary coils wound. The primary consists of 500 turns of 20 D.C.C., and is wound on one limb as indicated.

The secondary, which is 50 turns of 14 D.C.C., is wound on the other limb. The secondary coil has a tap brought out at the 25th turn, and is connected to a 2-point switch. This permits of voltage regulation when charging cells of low voltage. If desired, the coils can be former wound,

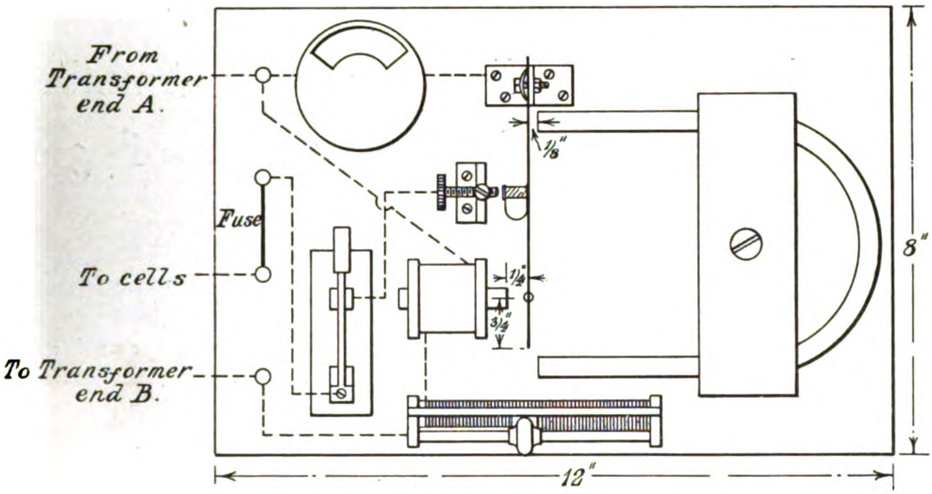


Fig. 7.—The lay-out of the rectifier and controls.

should be truly square and in line, so as to grip the reed from its operating point firmly.

A transformer is necessary to step the line voltage down, and is of closed-core type. Many excellent transformers can be picked up cheaply second-hand, which may be easily adapted. The construction of an efficient type will, however, be dealt with. It should be made from a good grade of transformer iron, preferably stalloy, the laminations being about ·016″ thick. Each sheet should be japanned or shellacked before assembly, to prevent eddy currents.

The core is built up to dimensions shown on drawing. Note carefully the method employed to interlock the corners to com- taped, and then slipped over cores. The coils should be well shellacked and baked in a warm oven.

The transformer is now assembled by attaching the yokes, which are also made up of alternate long and short sections. The whole of the laminations must be tightly clamped to avoid noise in operation.

The ammeter for indicating charging rate should be of the moving coil type, preferably with central zero.

Moving iron and hot wire instruments give incorrect readings, owing to the fact that the charging current is a pulsating one.

The resistance to regulate the rate of charge should be wound with 18 S.W.G. to

a resistance of 4 ohms, on a slate base, and fitted with a slider. The 4-amp. 3-ohm type supplied by the Zenith Co. is excellent for this purpose. This regulating resistance and the 2-point switch are mounted on the transformer.

Considerable charging rate control is obtained by the adjustment of the contact. 1-16th" is the usual allowance between contact screw and contact on reed, when the latter is at rest. In the preliminary tuning up of the instrument all the resistance should be included, until sparkless operation is obtained. Otherwise, if the reed falls out of step a very destructive arc will be set up at the contact, which will be speedily destroyed. Rough tuning of reed is accomplished by alteration of effective length at supporting bracket, fine tuning by sliding weight.

The polarity of D.C. terminals must be found, either with pole finding paper or by immersing the two wires in slightly acidulated water, noting wire which gasses most, that being the negative.

In conclusion, it is hoped that all the essential details have been adequately dealt with, and the writer is confident that the instrument will give satisfaction if these instructions are adhered to.

The Design of a Radio Frequency Amplifier to Operate on a Wave-length Range of 300 to 1,000 Metres.

By G. L. MORROW, F.R.S.A.

The modern tendency among experimenters is to use critically tuned amplifier circuits. Below will be found the design for an aperiodic amplifier which obviates a multiplicity of adjustments.

Preliminary Consideration.

A RECEIVER was desired to operate with the maximum degree of efficiency combined with high sensitivity, on a wave-length range of approximately 300 to 1,000 metres, being primarily required to give high and sustained amplification on 300, 450, 600, and 900 metres ship and shore spark traffic. Other considerations were in the order of importance that the amplifier should

1. Possess the highest degree of sustained amplification over the above band of wave-lengths combined with the fewest number of critical adjustments.

2. On an average amateur aerial (confined to the standard G.P.O. aerial limits) be capable of receiving 600 m. ship spark traffic up to 1,000 miles radius. This last figure being the night range under normal atmospheric and climatic conditions.

3. Be capable of

A. Sustained amplification with

B. Quick "search" properties.

When used for 450 ms. spark D.F. work with either a frame or open Bellini-Tosi D.F. aerial.

4. Be of reasonable dimensions and weight with regard to portability.

Dealing with these requirements in order, and in fairly full detail, two outstanding points had a considerable bearing on the design. These two points are, first, owing to the fact that the station is situated in a country locality with somewhat poor facilities for charging accumulators, it was desired that as few valves should be employed compatible with the degree of amplification aimed at. This necessitated the employment of valves with a low current consumption, and in passing it should be noticed that at the time

when the amplifier was designed Dull Emitting valves were still in an experimental stage. Secondly, owing to the locality of the station, facilities for obtaining spare high tension units were poor, especially when it is remembered that a high-tension battery often fails at a moment's notice. This consideration, apart from reasons of economy in maintenance, had considerable influence on the design, since the total anode feed current was required to be as low as possible.

B. The tuned anode system.

C. Aperiodic transformers, *i.e.* transformers wound with resistance wire.

Undoubtedly method (A) would give the high degree of sensitivity and therefore amplification with the smallest number of valves, but it was considered that in order to operate efficiently over the band of wavelengths required, the transformer primaries would need to be tapped and fine tuning, which is especially needed to overcome

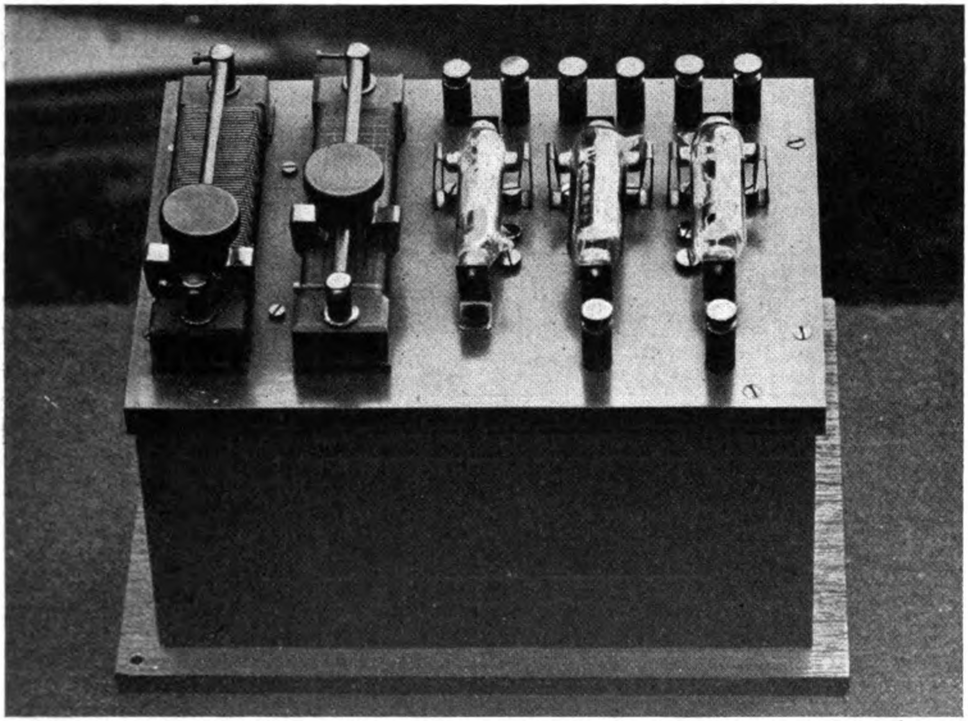


Fig. 1.—General view of amplifier.

Coming now to the chief requirements of this amplifier it will be seen that they are essentially a highly sensitive spark receiver with critical adjustments reduced to a minimum, the desideratum being a sensitive high frequency amplifier operating efficiently from 300 to 1,000 metres inclusive with the ease and simplicity of adjustment of a single valve receiver. The various methods of obtaining the radio-frequency amplification required, which were considered by the author in the preliminary stages of the design, were :—

A. Tuned copper-wound, high-frequency transformers.

jamming on 600 ms., accomplished by means of a small variable condenser shunted across the primaries. It was estimated that with this method of amplification two stages of radio-frequency would be required to fulfil satisfactorily condition 2, but owing to the number of adjustments which would be necessary to cover from 300-1,000 metres it was not considered practicable to employ this method.

Method (B), *i.e.* the tuned anode system was next considered, but here again, whilst the number of adjustments required is decreased owing to the fact that tappings

would be discarded with only a small decrease in efficiency, it would still not comply with condition 2. Furthermore the author is of opinion that since with this method of amplification tuning is so extremely sharp—even when a vernier condenser is used paralleled with the anode inductance condenser— that more than one stage of tuned anode amplification is almost impossible in an amplifier operating under commercial quick-search conditions. Good audibility of approximately R.6 strength was required on standard 1½ k.w. ship spark stations on a night range of from 500 to 600 miles, and it was considered extremely doubtful if only one stage of high-frequency amplification would satisfy this condition.

The author therefore decided to employ method (c), that is, radio-frequency transformers wound with resistance wire giving high damping and consequently aperiodic with respect to the resonant frequencies.

With this type of transformer having an optimum magnification value at 600 ms., good sustained amplification will be given over the range of 300 to 1,000 metres, the amplification however being considerably greater at 1,000 ms. than at 300 ms., owing to the resonance curve of this type of transformer.

Having decided to employ aperiodic high-frequency amplification, the number of such stages had next to be determined.

Previous investigation into the relative magnification obtainable with a copper wound transformer against an aperiodic transformer, led the author to adopt a round figure of 50 per cent. less amplification in the case of an aperiodic transformer other things being equal, so that since two tuned transformers had been considered sufficient to satisfy rondition 2, four aperiodic transformers were shown to be necessary.

This entailed the use of five valves in all, which number was considered to be too great from the point of view of economy in filament watts and anode feed current, yet two aperiodic stages only did not appear to guarantee the margin of safety on weak signal strengths that was desired.

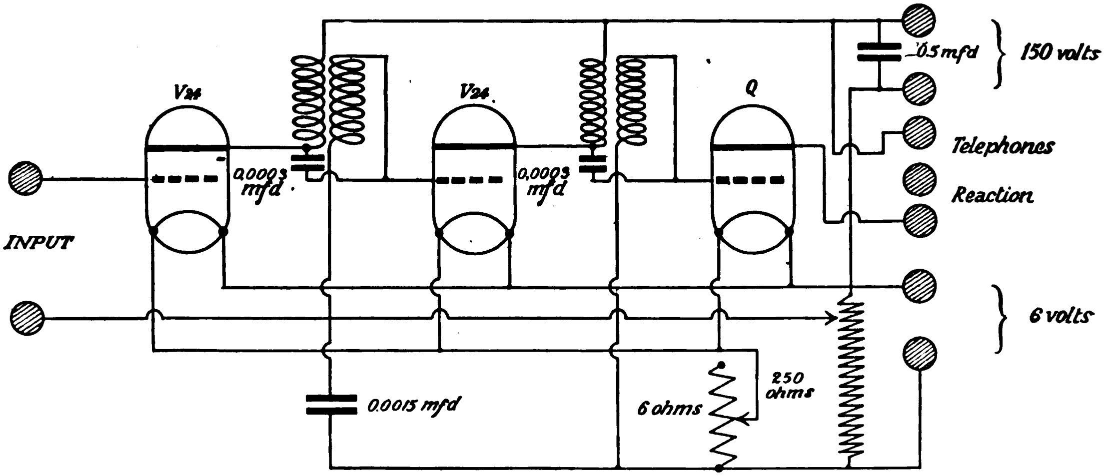


Fig. 2.—Wiring diagram of amplifier.

The original aim had been to produce a receiver fulfilling the various requirements which have been specified without the employment of regeneration, but it was now decided to incorporate regenerative working and in so doing to ensure that two stages of aperiodic amplification would satisfy the somewhat exacting conditions which were required. The general scheme of design had now been fairly rigidly determined as a 3-valve radio-frequency amplifier; the first two valves coupled with aperiodic resistance-wound transformers, the third valve functioning as a rectifier of the amplified radio-frequency impulses.

At this stage it may be of interest to note that as regards actual cost, the figure for the two transformers wound with eureka wire

is just under the cost of a receiver utilising copper wound transformers with their attendant switches and variable condensers.

Having decided on the general scheme of design, the number of controls was next considered, and it was deemed necessary that two filament rheostats should be employed one in common to the H.F. stages and one to control the operating characteristic of the rectifier valve.

It was further decided that a potentiometer was necessary in common to the H.F. stage in order to operate at the highest efficiency by means of grid control.

wound transformers a voltage drop between the + H.T. supply and the anodes of the valves would, for the windings required, be in the neighbourhood from 20 to 30 volts, thus the high-tension battery would need an E.M.F. of approximately 100 volts in order to maintain the anodes at 70 volts.

Furthermore an examination of the average characteristics of the R. type valve will show that to operate on the straight portion of the anode current grid volts curve (for E=70), with zero grid potential, the anode current will be in the region of 1 milliamp., which for 3 valves would give an anode feed of probably

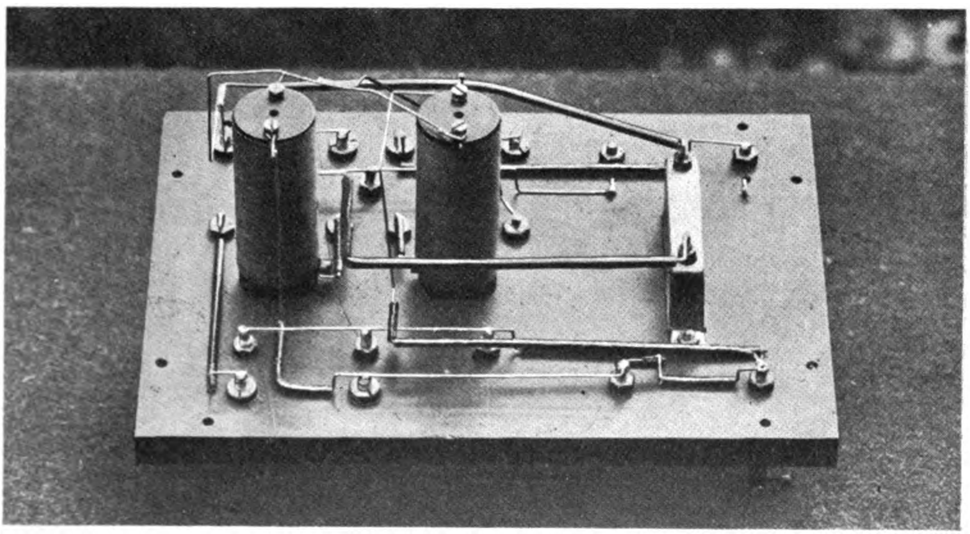


Fig. 3.—Underside of panel showing transformers and H.T. dyepass condenser.

nearly 4 milliamps., which was considered to be rather high.

At this point arose the determination of the type of valves to be employed and also the means to adopt for rectification.

The Marconi R. type valve was first considered, the average working conditions of which are as follows :—

Filament volts, Ef, 4.00 volt.

Filament current, If, 0.75 to 0.8 amp.

Plate potential, E, 60-80 volts.

To give a reasonable length of operation on one charge of the filament accumulator, it was decided that a 6.0-volt battery would be necessary to balance the voltage drop of an average 60-volt battery when discharging at approximately 3 amperes.

The plate potential was next considered and it should be noted that with resistance-

The standard Marconi receiving valve type V24 was next considered and for the H.F. stages was finally adopted for the following reasons :—

1. 5-volt filament being well within the economical running of a 6-volt battery.

2. Low anode current for H.F. amplification at zero grid potential—under 1 milliamp.

3. Low anode voltage required, *i.e.*, 30 volts.

4. Very low internal capacity.

Coming now to the method of obtaining rectification both anode and grid rectification were considered and since the writer has had considerable experience with Marconi receivers employing the former method, it was

decided to rectify with a "Q" type valve, the grid being maintained at its best operating potential by means of a potentiometer. This necessitated one extra adjustment over that required by grid rectification by means of a grid condenser and leak, but as the combination of a separate filament rheostat and grid potentiometer on the rectifier constitutes a very efficient limiter for selective working on 600 ms., the extra adjustment was in this instance considered to be quite justifiable. The final circuit arrangement being shown in Fig 2.

The preliminary considerations having now been discussed and the main design scheme having been decided upon, it is proposed to give some detail of the actual construction.

Before proceeding further it may be advisable to point out that in a radio-frequency amplifier of this type a tendency toward self-oscillation may cause a certain amount of trouble, if one or two important factors are lost sight of.

Although this type of amplifier is certainly far less liable to burst into self-oscillation than either of the tuned types considered above, this tendency, nevertheless, may show itself if the transformers are placed too close together. The writer has found that if high-frequency transformers of the type used in this amplifier are placed *less* than approximately three inches between centres, a certain amount of self-oscillation may occur, necessitating an adjustment of the grid potentiometer in order that a positive potential may be applied to the high-frequency grids.

The use of the potentiometer in this manner will stop any tendency towards self-oscillation but at the same time it should be noted that it will reduce seriously the efficiency of the circuit owing to the damping effect of the positive grid current set up by the grids themselves being positive. If, however, the transformers are placed no closer than the minimum distance above, it will be found that the circuit is perfectly stable under all conditions, even when the plate voltage is as high as 150 volts

It may be found helpful also to remember one other factor which will lead to increased efficiency, and that is, that the input and output leads to the H.F. transformers should be short and well separated not only from themselves but from those of the other transformers. The actual arrangement of these leads is shown in Fig. 4. If careful attention is paid to this, and to the preceding point, it will be found that the only work the grid potentiometer will be called upon to do is to operate the H.F. amplifying valves at the most efficient points on their characteristics;

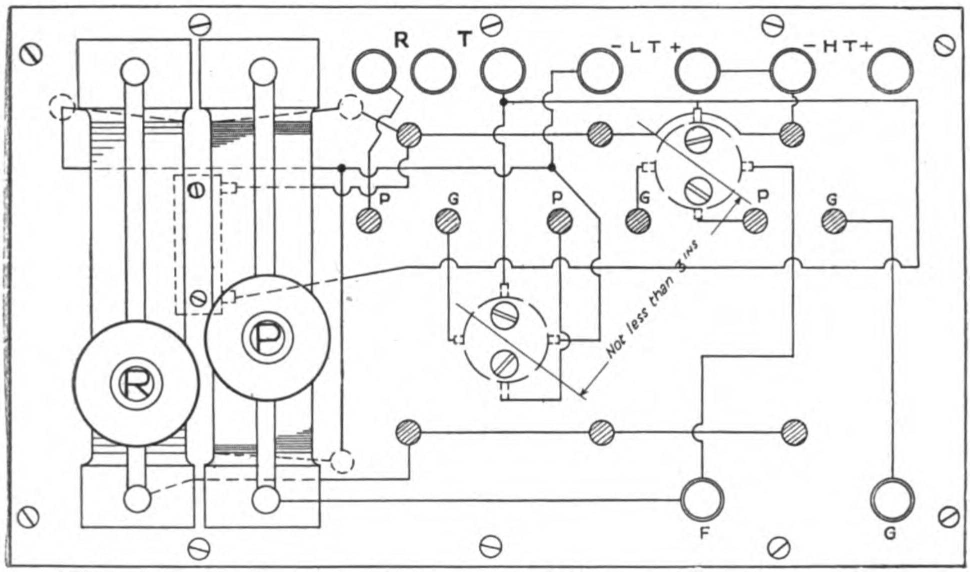


Fig. 4.—Diagram showing wiring lay-out.

this, in the writer's opinion, is the legitimate function of a H.F. grid potentiometer which in a carefully designed and assembled amplifier should not be called upon to damp out oscillating tendencies by means of positive grid potential.

In the design of highly damped aperiodic transformers, such as used in this amplifier, it is essential that the maximum degree of coupling should be employed between the primary and secondary windings. Even in such aperiodic transformers there is a certain resonance peak on the curve which can be plotted showing amplification against wave-length; any weakening of this coupling between windings tends to make this peak far more pronounced, and if this is the case the great advantage of this method of high-frequency amplifications, namely, sustained amplification, is immediately lost. This coupling is also increased by means of small condensers of 0.0003 m.f.d. capacity which are connected between the windings themselves; these condensers helping still more to flatten out the resonant peaks of the transformers. In order to obtain maximum coupling between windings it is necessary to wind the transformers with single-layer primaries and secondaries, both windings being in the same direction with a one to one ratio of turns.

The essential high damping of the transformer winding is obtained by the use of resistance wire, which, in the amplifier in question consists of No. 46 S.W.G. Eureka wire. In passing it may of interest to note that the writer's experience with this type of transformer is that, using this gauge of resistance wire wound on formers with a diameter of 1⅛ inches, the optimum wave-length is approximately equal to the number of turns, that is to say, for 600 ms. work both primary and secondary are wound with 600 turns. Finally Fig. 5 shows the relation-

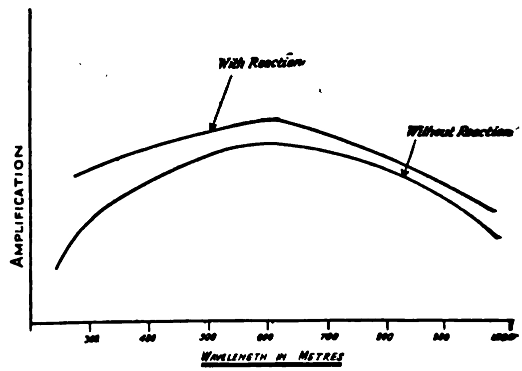


Fig. 5.—Amplification curves with and without reaction.

ship between amplification and wave-length both with and without re-action, the curve being, of course, only relative, since the degree of amplification will vary according to the station which is being received. Whilst considering this effect of reaction it should be noted that some method of reversing the reaction coil leads should be incorporated in the design, since on coming down to 300 metres a phase reversal occurs in the neighbourhood of 400 metres, thus necessitating a reversal of the reaction coil itself on the lower wave-lengths.

Telegraphy on a Power of 30 Watts.

Since going to press with "The Month's DX," we have received some details of what is surely a world's record for amateur transmission. Mr. E. J. Simmonds, 2OD, who is too well known to need an introduction to readers of Experimental Wireless, worked for some considerable time Mr. Dodman, of Summit, New Jersey, U.S.A., using an AT40x valve. The input was 35 M.a. at 900 v., and the transmission was conducted as easily as if the stations were not situated more than a few hundred miles apart. This in itself is sufficient evidence of the efficiency of the apparatus and the skill displayed in its design and adjustment.

Discussion on Loud Speakers for Wireless and other Purposes.*

THEORY OF LOUD-SPEAKER DESIGN: SOME FACTORS AFFECTING FAITHFUL AND EFFICIENT REPRODUCTION.

By L. C. POCOCK, B.Sc., A.M.I.E.E.

If it is assumed that properly amplified and undistorted speech voltage is available in the output circuit of a final amplifier, the problem is to procure the reproduction of speech efficiently and faithfully. The exact criteria for the reproduction of speech are better known than for music, but it is probably safe to say that a system capable of reproducing speech perfectly will give a highly satisfactory performance with music.

If V is an impressed voltage of any frequency or amplitude within the region to be amplified without distortion, and P the resulting alternating air pressure outside the system, the conditions are :—

$$P=AV$$

where A is an efficiency constant independent of the frequency and amplitude. It is also necessary that there shall be no asymmetric distortion, that is, any single frequency V must produce only the corresponding single frequency P. This condition is also expressed by the equation above.

Present-day electro-magnetic loud speakers are, without exception, a compromise between relatively good efficiency and good quality, such efficiency as can be secured being obtained only with the aid of mechanical resonance, which is contrary to the criterion for faithful reproduction given above. Further, although telephonic speech has generally been handled in the past as a steady-state problem, recent improvements in transmission have rendered the transient phenomena associated with consonant sounds and every change of amplitude of some importance. The reproduction of severe transients cannot be perfect in any resonant system or in any system containing mass and stiffness, even though the damping be such as to prevent any natural oscillation; the severity of transients actually encountered in speech is dependent on the damping of the vocal resonances, and information on this subject, together with like information on the auditory mechanism, might indicate the desirable degree of damping from the point of view of transient phenomena. It is clear that the use of resonance to increase the efficiency cannot be pushed too far.

Practical loud speakers consist of a rather sharply resonant system working into an acoustical load, namely, a horn. It is not quite accurate to describe the horn as a load, because the useful work is the energy transmitted through the horn. The horn is operating in a capacity analogous both to an electrical transformer and to an electrical transmission line. The likeness to a transformer is seen in the passage of energy from the high mechanical impedance of the diaphragm to the low impedance of the open end through the coupling device, which reduces energy reflection to a minimum and aims at obtaining the greatest possible transfer of energy. The likeness to a transmission line lies in the propagation of waves across the non-uniform section of the horn; the analogy is to a non-dissipative line containing distributed inductance and capacitance, the line constants changing steadily from end to end of the line in such a way that the impedance measured at one end of the line is high, and that measured at the other end is low. Such a system would form a maximum energy coupling between two different electrical impedances.

The acoustical impedance of a horn at its small end depends a good deal on the cross-section and also varies with the solid angle and the form of the horn, but, as in electrical analogies, the impedance is also a function of the impedance into which energy is delivered, *i.e.*, at the open end. Another view of the acoustical impedance at the small end is to regard it as the impedance of the large end modified by the horn through which it is measured. In general, the horn impedance also varies with frequency, and, though horns of approximately uniform impedance can be made, it is clear, from a consideration of the varying mechanical impedance of the diaphragm, that such a horn is not necessarily the best.

These are some of the factors which enter into the performance of a horn. The practical considerations are usually those of size; for indoor use the horn must not be too long, so that the problem is equivalent to attempting to obtain an electrical line of length equal to a wave-length of less and having a very much higher line impedance measured from one end than when measured from the other end. The acoustical impedance is virtually coupled to the diaphragm, so that some idea of its variations with frequency can be obtained by observing the motional impedance of the receiver. A large number of horns, of a size suitable for use in private houses, have been examined in this way, and resonances of varying degree have been found in all; larger horns might, however, be expected to show lesser effects.

The resonance of a receiver without horn may be

* Two papers of particular interest to the experimenter which, amongst others, were read before a joint meeting of the Institution of Electrical Engineers and The Physical Society of London, on Thursday, November 29, 1923.

such that the diaphragm vibrates with more than 50 per cent. of the amplitude at resonance over a frequency region about 100 periods wide. When the horn is put in place the diaphragm is made to do more work and the resonance is made less sharp. The new damping co-efficient cannot be simply expressed, because the resonance is no longer simple but is complicated by the coupled horn resonances.

The actual pressure variation in the air when the receiver is excited at different frequencies can be measured. Figs. 1 and 2 show the characteristics

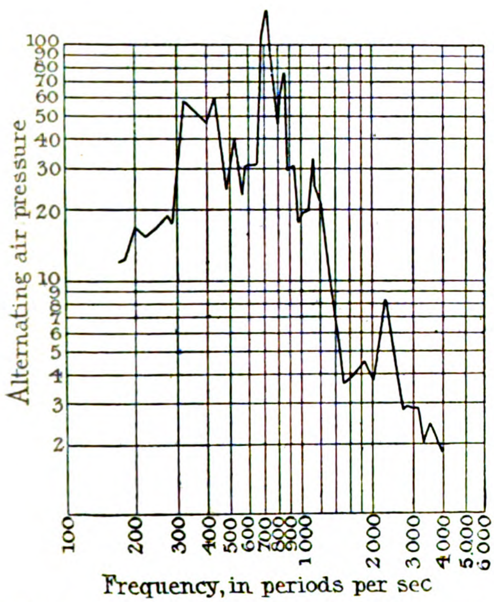


Fig. 1.—Alternating pressure output of loud-speaking receiver corrected for impedence of circuit and receiver.

of two types of receiver. The curve in Fig. 1 is for a flexible diaphragm driven by a small armature supported on a spring. The effective moving mass is not appreciably greater than that of the ordinary telephone receiver. The curve is an average of the results of five receivers and shows definite peaks in the lower frequency region, due to the horn. It is seen that the distortion due to these resonances is small compared with the general effect, due to the mechanical resonance of the system. This is an important point: horn distortion can be brought within reasonable limits; the receiver mechanism is often responsible for defects of tone for which the horn is blamed.

In connection with Fig. 1 it may also be stated that the perfection of reproduction is a great deal better than the appearance of the characteristic would suggest; the contracted logarithmic scale disguises the really rather gradual fall of the curve at the higher frequencies; even at the extreme end of the curve the highest frequency shown is reproduced with sufficient intensity to add greatly to the quality of reproduction.

Fig. 2 is the characteristic of a loud-speaker of the iron-diaphragm kind, similar in principle to the ordinary telephone receiver; in this case the curve is an average of several tests taken on the same receiver. The frequency of maximum response is seen to be a little lower than in Fig. 1, and the curve drops somewhat steeply between 1,000 and 2,000 periods per sec. (p.p.s.).

In both the above cases the receiver output is corrected for the impedance of the associated amplifier, that is, a fixed voltage is operating on the loud-speaker through a fixed resistance representa-

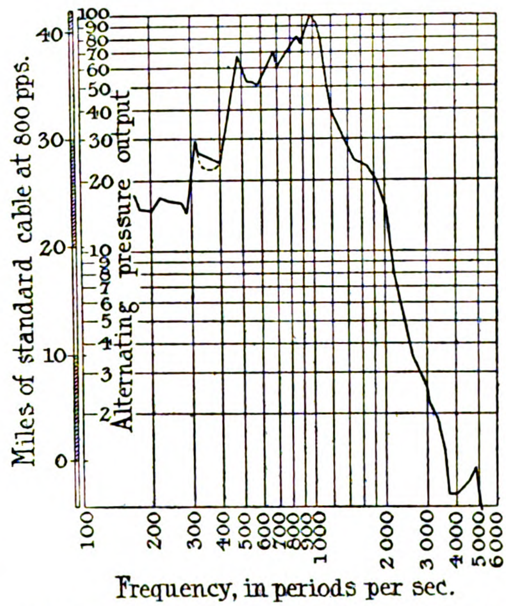


Fig. 2.—Alternating air-pressure variation with frequency for large receiver when used with constant E.M.F. in a circuit of which the output impedance is 1,000 ohms.

tive of the amplifier output impedance that would be suitable for use with the receiver considered. Since the impedance of most receivers at about 4,000 p.p.s. is two three, or more times as great as the impedance at 1,000 p.p.s., the reproduction of the higher frequencies is somewhat impaired due to this cause.

Receivers have been constructed in which large vibrating surfaces are used without a horn. It appears that the vibrating surface must be of such dimensions that there is difficulty in securing the necessary lightness of the moving parts, especially when the added mass due to the reaction of the air, is taken into consideration. In any case, the very important distortion due to the use of mechanical resonance to obtain good efficiency remains in evidence.

With regard to the mechanical construction of an electro magnetic receiver, the ordinary construction of a telephone receiver requires considerable modification if it is to handle more than a very small amount of power and, even when so modified, there is danger of distortion due to the asymmetrica

forces called into play by the passage of symmettrical currents. A receiver of the type giving the characteristic shown in Fig. 1 is capable of handling about 10 watts without a symmetrical distortion, because the armature is driven by symmetrical forces. The amplitude of vibration may be of the order of 0.01 inch.

To sum up, with present-day constructions of receivers, faithfulness in reproduction cannot be obtained beyond a certain degree without making receivers very inefficient. Reproduction can, by careful design, be made very satisfactory, but to obtain the very last degrees of perfection, *e.g.* by filters, enormous increases in the power amplification would be necessary to operate the receiver, in fact, valves of far higher power capacity than are used in any radio receiving sets. As it is an easy matter to obtain the present amount of amplification, it is seen that the chief interest in raising the efficiency of loud-speakers is to permit the application of quality-correcting devices, provided of course that increased efficiency is obtained without sacrifice of quality.

With regard to the overall efficiency obtained in loud-speaking receivers, it is probable that 1 per cent. is a high estimate and that a few tenths of 1 per cent. would generally be nearer the mark. The principal loss is iron loss, and (though lamination will reduce this) hysteresis still accounts for a very considerable loss on account of the high frequencies concerned. It does not seem likely that any great improvement in real efficiency can be obtained unless a magnetic material with exceptionally low hysteresis loss and good permeability is discovered. Small improvements are possible by building receivers on a larger scale and using more powerful magnets, but the necessity of making some part of the moving system of iron and low mass makes the employment of high alternating flux density in this vital part unavoidable.

The Sources of Distortion in the Amplifier.

By Professor C. L. FORTESCUE, M.A., M.I.E.E.

(1) Scope.

In this note the output P.D. from the rectifying valve of crystal is taken as the starting-point. With an ideal amplifier this P.D. is magnified and a current of precisely the same wave-form as the output P.D. from the rectifier is supplied to the loud-speaker. In many actual amplifiers, however, the wave-form is not faithfully reproduced and distortion is introduced.

(2) The Causes of Inaccurate Reproduction.

These may be put under the following headings :—

(*a*) Curvature of the valve characteristics.

(*b*) The use of intermediate circuits having more or less clearly defined natural frequencies.

(*c*) The unavoidable reaction effects present in most designs of note magnifiers.

(*d*) Unsatisfactory reproduction in the last (or output) transformer.

(3) The Effects of Curvature of the Anode Current Characteristics.

(*a*) *Resistance amplifier.*—The ideal resistance amplifier is as shown in Fig. 1, and consists of a valve with a non-inductive and capacityless resistance R_a in series with the anode and a condenser of very large capacity across the battery terminals. The valve characteristics may be conveniently plotted as a characteristic surface in terms of V_b and V_g, allowance being made for the resistance R_a.

The surface shown in Fig. 3 is the ordinary characteristic surface, the lines corresponding to constant anode current, but allowance is made for a series resistance of 10,000 ohms. The fluctuations of the grid P.D. above and below the mean value may be plotted below the diagram of Fig. 3 as at G. Then, by projecting up to the line PQ, corresponding to the given value of the battery voltage, the values of the anode current can be plotted above and below the mean value at C. A reference to Fig. 3 shows that the anode current wave-form can only be an exact replica of that of the grid P.D. when the constant-current lines are equally spaced along the line PQ. Thus, if the surfaces are plotted out for any given value, the possible range of anode current and grid voltage over which faithful reproduction can be obtained will be easily seen and the appropriate values of V_{g_0} and V_b can be chosen. The values taken in plotting Fig. 3 are $V_b = 200$, $V_{g_0} = -4$. The amplitude of the fluctuations of V_g is 3.5 volts and of i_a, 1.75 mA.

(*b*) *Transformer amplifier.*—Except in the last stage, a transformer in the anode circuit should closely approximate to a resistance. When very heavily damped, due to its own losses and the load of the valve, and when near the resonant point, this is actually the case. The effective resistance to the alternating P.D.'s (which are the ones under consideration) is, however, very much greater than the resistance of the anode winding as measured by direct current. The resistance must be ascertained by A.C. bridge methods at the resonant frequency. Some transformers having a direct-current resistance of the order of 2,000 ohms are found at the resonance point to have effective resistances of 200,000 to 300,000 ohms when loaded on the secondary side with resistances corresponding to the grid resistance of the next valve. The representative characteristic surfaces must therefore be plotted for this high value of R_a and not for the d.c. resistance; the latter is only used to obtain effective starting-point for any actual battery voltage.

For frequencies other than the resonant frequency of the transformer the conditions are more complicated, and merely plotting the characteristic surface with a correction for a series resistance is insufficient. The surface must be plotted without correction and both the grid and the anode fluctuations must be allowed for. The line PQ of Fig. 3 becomes a curve—an ellipse in the case of two pure

sine waves—and so long as this curve remains within the zone where the constant-current contours are equally spaced the reproduction will be satisfactory.

(4) Effect of Curvature of the Grid Characteristics.

If the grid voltage fluctuations have any considerable positive values the grid currents will be quite appreciable, and the wave-form of the grid current will differ very widely from that of the grid P.D. Fig. 2 shows approximately the curve of the grid current corresponding to the conditions assumed for Fig. 3. The grid currents will generally react on the source of P.D. and lead to a change of wave-form somewhat in the same way that the wave-form of the E.M.F. of an alternator s dependent upon the wave-form of the current which it is supplying.

be greatest at the resonant frequency. Thus any sustained harmonic having this frequency will be unduly pronounced and the speech will appear "tinny" or "drummy" depending upon the pitch of the accentuated harmonic. The larger the number of stages of amplification that are used the more marked is the effect.

In the case of those high-frequency components which are not sustained, the effects are less pronounced. This effect is thus most noticeable with musical sounds and with the vowel sounds. Secondly, for frequencies other than the resonant frequency the transformer is no longer equivalent to a resistance, and complications arise from the relative phase of the grid and the anode potential fluctuations on account of which it becomes very difficult to determine the wave-form of the anode current when the amplitudes are fairly large.

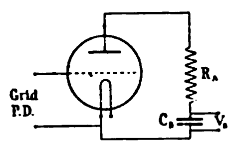


Fig. 1.—Resistance amplifier.

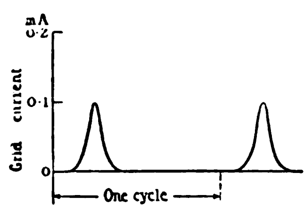


Fig. 2.—Wave-form of grid current with conditions of Fig. 3.

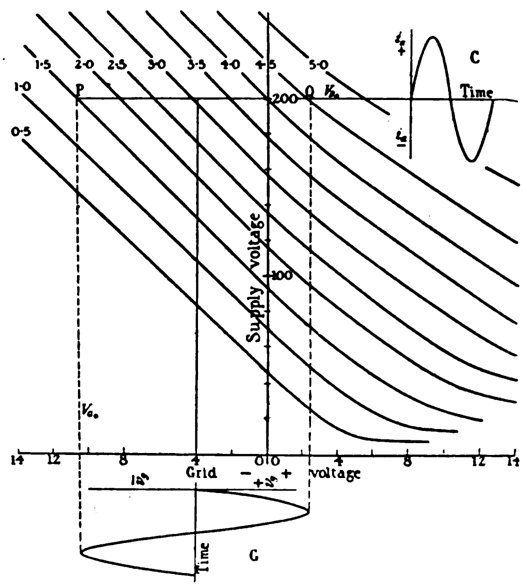


Fig 3

The only way of avoiding this difficulty is to render the effect of the grid current negligible. Valves have not yet been produced in which the grid current is negligible when the grid is positive and the anode voltage is low, and consequently positive values of the grid voltage must be avoided. This gives another limitation to the range of the anode current characteristic curves that can be used, and indicates that the anode battery voltages should be high, and that the mean grid voltages should be considerably negative.

(5) Effect of the Natural Period of the Intermediate Circuits.

This trouble arises in the case of a transformer amplifier. In the first place any marked resonance means that the effective impedance in the anode circuit is dependent upon the frequency. The impedance—and therefore the amplication—will

(6) Reaction Effects.

These effects are well known, particularly in high-frequency amplifiers used as self-heterodynes. They are equally important, however, in note magnifiers, as is shown by the tendency of a high-power magnifier to "howl" when adjusted for maximum amplification. This reaction effect is greatest in transformer amplifiers, and is attributable to the capacity between the electrodes of the valves. The coupling between consecutive grid and anode circuits tends to produce stability and decreases the effective amplification. But where more than one stage is employed there is also a coupling between a grid circuit of one valve and the anode circuit of the valve next but one to it. This coupling acts through the two valve capacities in series, but if the voltage step-up per valve is more than two the coupling effect tending towards instability is greater than that from the immediately adjacent

anode circuit opposing instability. With three valves the effect of the last anode circuit on the first grid should be in the direction of stabilising, but on the second grid circuit it may well produce instability.

The effect of this reaction is that with sustained waves the frequency which renders the system most nearly unstable attains to a higher amplitude, relatively, than other waves of other frequency.

It seems probable that there are in general several frequencies which are thus accentuated, but owing to the similarity of the consecutive stages in most amplifiers these frequencies are close together and are usually near the natural resonance point. The resulting effect is thus an accentuation of the defects arising from marked resonance.

The pure resistance amplifier is not entirely immune from the effects of reaction unless the condenser across the anode battery is of very large capacity indeed. Under certain circumstances, also, if the capacity across the anode resistance is appreciable a resistance amplifier will "howl" owing to an oscillation being set up in the same way as in the "Kallirotron."

(7) Distortion in the Last Stage.

The last stage is not infrequently a source of serious trouble for two reasons :—

(i) The amplitudes are large.

(ii) The "load" on the output transformer—*viz.*, the winding of the loud-speaker—is inductive and this inductance is not constant.

With regard to (i), the output required for a sustained musical note is of the order of 10 mA (R.M.S.) at 5 volts (R.M.S.). To give an equivalent volume of sound with ordinary speech a peak value of perhaps double these figures will be necessary, and after allowing for the losses in the transformer it seems that the output from the anode circuit of the last valve will be equivalent to an alternating current of peak value 30 mA at an alternating P.D. of peak value 15 volts. A transformer is almost invariably used, and the actual values would more probably be 10 mA at 45 volts. This involves a valve giving an emission current of perhaps 50 mA, with a fluctuation of anode current over the range 15 to 35 mA ; and a voltage at the anode of perhaps 120, fluctuating between the limits of 75 and 165. General numerical considerations such as these show the necessity for valves of considerable output in the last stage.

High battery voltages are also necessary—in the above case the steady fall of P.D. in the anode circuit would be of the order of 50 to 100 volts, and a battery giving something in the neighbourhood of 200 volts would be unavoidable.

With regard to (ii), owing to the inductive nature of the load the last stage cannot be regarded as being even approximately a resistance, and the same effects are noticed as with a transformer operating out of resonance.

(8) Conclusion.

With properly designed valves and circuits it does not appear that any serious distortion can be charged against the amplifier. Valves giving considerable power output must, however, be used in the last stage.

Some resonance effect seems unavoidable in the transformers, and may be accentuated by reaction. The presence of this effect may, however, be an advantage owing to the fact that it can be used to some extent to compensate for defects in other parts of the equipment.

Aerial Design for 200-metre Transmission.*

On Friday, December 17, a meeting of the Radio Transmitters' Society was held at the London School of Economics, the President of the Society, Capt. P. P. Eckersley, being in the chair. An informal discussion on aerial efficiency on short wave-lengths was opened by Mr. L. G. Morrow, who gave a short talk on "Aerial Design for 200-Metre Transmission."

Mr. Morrow's Paper

I think that you will all agree that the efficiency of our stations depends, first and foremost, on the efficiency, or otherwise, of the aerial, or more correctly speaking, the aerial-earth system, and if we are to pursue this search after efficiency to a satisfactory conclusion, it means that as much as possible of the power which we put into the aerial must be available as *usefully* radiated energy.

To obtain the greatest proportion of useful radiated power it is necessary to minimise to the greatest possible extent the various losses which occur in the aerial system, and it is mainly on the reduction of these losses that I expect the discussion which follows will centre round.

I will, therefore, try to point out briefly how these various losses occur, and by what means we can minimise them in our aerial design.

Any aerial system when supplied with H.F. currents absorbs power, some of which is radiated in the form of an electro-magnetic field, and represents useful power, whilst the rest is absorbed in various ways, and constitutes a total loss, since it contributes nothing towards the radiated power.

Now all the power absorbed by the aerial can be regarded as if it was expended in a *Resistance* of such a value that it would absorb the same power expended in the system for the same current flowing in that circuit. This resistance is a fictitious quantity, and is known as the "effective" resistance.

This effective resistance may be divided into two parts.

(1) Radiation Resistance, and

* A paper read before the Radio Transmitters' Society on December 17, 1923.

(2) Loss Resistance.

Taking the former, we may again define this as being a fictitious resistance, the value of which will absorb the same power as is radiated for the same, current as flows in the aerial, and is, therefore, the measure of ability of the aerial to radiate power. An aerial with a high radiation resistance will be a better radiator than one with a low radiation resistance, hence we should design our aerial so that the radiation resistance is the greatest *percentage* of the total resistance.

If we examine the formula which gives us the radiation resistance (*i.e.*)

$$R_r = 60\pi^2 \frac{h^2}{\lambda^2}$$

we see that R_r is dependent on two qualities, namely height and wave-length; in other words, R_r is directionally proportional to the square of the height, and inversely proportional to the square of the wave-length. Now, as far as we are concerned, our wave-length is within quite small limits fixed by the powers that be; therefore in order to obtain a high percentage radiation resistance we have only the height left as a variable quantity.

Unfortunately in most cases the heights of our aerials are directly proportional to the depths of our pockets—it is in my case—and even if it was not a question of expense, we cannot go on increasing the height indefinitely, since to do so will, in all probability, bring our fundamental higher than we wish.

The only remaining alternative is, therefore, to reduce the loss resistance as much as possible, at the same time keeping the radiation resistance as high as possible by careful consideration of the relation between fundamental wave-length and operating wave-length, and by getting as much height as we can.

The loss resistance of an aerial is due to a number of separate losses, which we can enumerate as follows:

(1) Dielectric losses in the neighbourhood of the aerial.
(2) Ohmic resistance of the aerial itself.
(3) Ohmic resistance in the ground or counterpoise.
(4) Eddy current losses in nearby conductors.
(5) Leakage losses.

Before we proceed further, it will probably simplify matters to show these losses graphically, including R. Of the five losses we have just mentioned, the first and fourth are, in many cases, outside our control, but we can certainly reduce the remainder as far as possible by careful design.

Taking these losses in order, the dielectric losses are due to hysteresis phenomena taking place in such materials as the masts, stays, trees in the vicinity of the aerial, etc., and these losses increase directly as the wave-length. On 200 ms these absorption losses should not amount to very much, but we can reduce these as much as possible by keeping the ends of the aerial as far as practicable from the mast, especially the free end, breaking the stays with insulators and careful design of the lead-in tube. (In passing, I might perhaps mention the fact that in my own station I was troubled by harmonics when the stays were broken, but by breaking each stay into three I was able to cure this.)

Ohmic Resistance.

Very little need be said about this, save that the aerial wire should be of large cross section and good conductivity. The large cross section may be obtained by using stranded wire, in which each strand is insulated to prevent the skin effect increasing the resistance. Joints should be eliminated as far as possible, and where occurring should be well sweated.

Ohmic Resistance in the Ground or Counterpoise.

I think you will all agree that attention to the earth resistance is of paramount importance, and unless you are the fortunate possessor of a constantly perfect earth, I think the counterpoise is the only way to reduce our earth losses. When energy is delivered to an aerial, a large portion of this energy is dissipated into the neighbouring ground and is not recovered, but if we arrange some kind of reflector between the aerial and the earth, and make this reflector in comparison with the earth proper an almost perfect conductor, then we shall be able, to a certain extent, to minimise these losses.

The function of such a reflector or counterpoise is, therefore, to intercept the downward radiation from the roof of the aerial, and to carry the return current on the wires forming this counterpoise rather than the earth.

According to Maxwell, an *earthed* counterpoise with wires 1 ft. apart and 2 ft. 6 ins. above ground, will carry about 80 per cent. of the current, leaving 20 per cent. in the ground, and if the counterpoise is insulated there is less than 1/1,000 per cent. earth current.

Now usually domestic troubles will ensue if we arrange a counterpoise at only 2 ft. 6 ins. above ground; therefore, we are practically limited to a minimum height of about 7 ft. I am afraid time does not permit a full consideration of the design of counterpoises, but you will find in the *Proc. Inst. Elec. Engineers*, May, 1922, what I think is the finest modern treatise on this subject, by Mr. T. L. Eckersley.

We should, however, design our counterpoise in such a way that, if possible, it extends on both sides and at each end to a distance equal to half the height of the aerial above it, paying as much attention to insulation as in the aerial itself. The wires forming the counterpoise should obviously have as little ohmic and H.F. resistance as possible, and should be spaced about 1 ft. apart, being suspended on triatics attached to metal posts.

The ensuing discussion was characterised by its unconstrained nature, the free exchange of ideas, and the genuine interest which was displayed on the whole question of aerial losses and their elimination. The discussion was contributed to by Messrs. F. L. Hogg, H. S. Walker, H. Andrewes, G. Marcuse, E. J. Simmonds, and others—not to mention the revered President.

Mr. Hogg explained an original scheme which he devised for arriving at an approximate value for the total resistance of a transmitting aerial. A blank experiment is first made by dissipating just enough power on the plate of a transmitting valve when not oscillating to make it visibly red-hot

in a given light, the exact power input to the valve being noted. The same valve is next made to oscillate and put a certain current into the aerial. The input and efficiency are adjusted until the anode is just as red as it was before. The total power input to the valve is again measured, and the difference between this and the first reading gives the power expended in the aerial system, whence, from a knowledge of the aerial current the aerial resistance can be calculated from the relation watts$=C^2R$.

The other speakers gave their experiences with various types of aerials, counterpoises, insulation and types of aerial wire.

Capt. Eckersley gave some interesting points of information, and once more exhorted us to try the "ratio-tap" for short-wave valve transmitters. He gave interesting instances of the losses which may occur when wood comes into the field of the aerial system. In one case a counterpoise was suspended by insulators from wooden posts, and it was found that undue losses were taking place; these losses were surprisingly reduced by substituting iron posts for the wooden ones. In another case an aerial lead-in was taken through an insulating bush in the wall of the wooden hut in which the transmitter was situated. The measured aerial resistance was found to be one ohm in excess of the calculated value; for some time this ohm could not be accounted for and could not be eliminated. When, however, the lead-in was taken through a large ebonite panel inserted in the side of the hut this ohm disappeared at once.

Capt. Eckersley also described the earth system used at the Bournemouth Broadcasting Station which gives good results when it is not practicable to instal the usual counterpoise. A system of radial wires are taken from the lead-in point, terminating in a large copper circle buried about 6 ft. below the surface of the ground. He also added his endorsement to the necessity of making all counterpoise wires exactly equal in length.

Answering a question put by Mr. Andrewes, Capt. Eckersley said that the introduction of a series condenser does not affect the radiation resistance of an aerial.

The whole meeting was a great success, both from a social and a technical point of view. So far there has been every indication that the Radio Transmitters' Society has a great future before it.

The Trend of Invention.

We summarise below the more important wireless inventions which have been disclosed during the month, special reference being made to those of immediate interest to the experimenter.

Still the problem of minimising interference appears to be engaging the attention of inventors. The number of patents taken out for systems for prevention of interference is legion, and still the problem seems far from being solved in a simple and effective manner. Several new arrangements are disclosed in the patent specifications printed during the last month. In British Patent No. 183,838 (British Thompson-Houston Co., of American origin) the aerial circuit is coupled to a circuit containing an artificial transmission line having an effective length equal to a number of wave-lengths of the signal to be received, which may consist of a solenoid, for example, or a series of inductances shunted by condensers. A number of coils are coupled to points one wave-length apart on this artificial line, and each of these coils is electrically connected to the grid circuit of a triode. These triodes have a common anode circuit. It is clear that when the grid coupling coils are coupled to points of the artificial line one wave-length (of the signal to be received) apart the E.M.F.'s in these coils due to the signal will be in phase, and thus all the triodes will assist one another in producing an effect in the anode circuit. If, however, the coils are not spaced exactly a wave-length apart the signal will produce a smaller effect in the anode circuit; hence if the arrangement is adjusted to receive a definite wave-length, other wave-lengths all have less effect, and thus the arrangement assists the usual resonance tuning, which is still employed, in the elimination of jamming. An example of this arrangement is illustrated in Fig. 1. The resistance shown at the right hand end of the artificial line is for the purpose of preventing reflection and should be made equal to the surge impedance of the line. An ordinary amplifier or detector is represented diagrammatically at B.

A different line of attack on the interference problem is shown in British Patent No. 187,986 (British Thompson-Houston Co. of American origin), which depends for its operation on the phase of the signal.

Broadly, this invention appears to reside in making the signal to be received supply the anode potential to a triode as well as the usual variation of grid potential. Thus, unless both the anode and grid potentials are substantially in phase no current will flow in the anode circuit of the valve.

The simplest arrangement is shown in Fig. 2. The aerial circuit is coupled both to the anode circuit and grid circuit of a triode. In the grid circuit is included a phase shifting device A, so that the phase relation between the two potentials may be adjusted. It is necessary, in order to eliminate interference, that the anode tuned circuit be sharply tuned to the signal, since it acts as a flywheel circuit, and fixes the phase of the system.

The beats formed as the result of interaction of a C.W. signal with a locally generated wave may be treated in the same way, the flywheel circuit then being tuned sharply to the beat-frequency.

Another modification is shown in Fig. 3 for using this principle to increase the directional properties of aerials. Two directional aerials at preferably right angles are used, and the E.M.F. in one aerial is applied to the anode circuit of a triode and in the other to the grid circuit by way of a phase shifter, represented by E. In the diagram A and B represent detectors, and C a local oscillator. In this case the arrangement is working at the beat frequency.

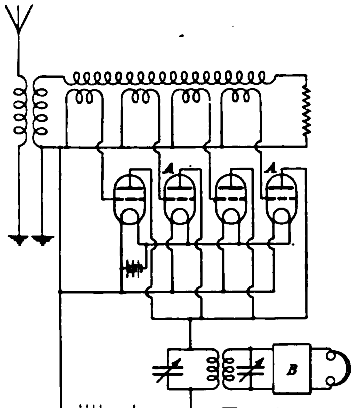


Fig. 1.

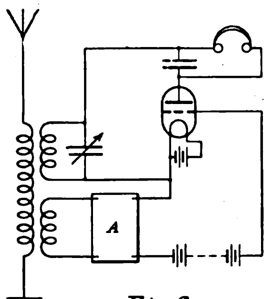


Fig. 2.

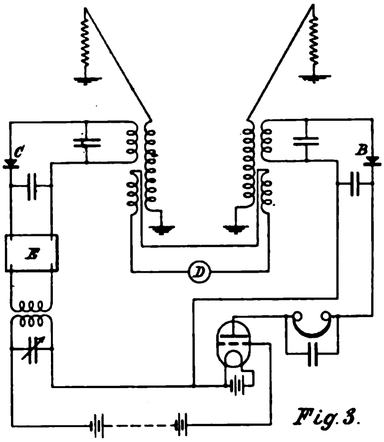


Fig. 3.

In order further to reduce atmospheric disturbances current limiting devices may be used in any except the flywheel circuit.

Another arrangement for the prevention of interference is shown in British Patent No. 185,397 (of French origin). The arrangement described by this patent specification essentially consists of a multi-valve aperiodic amplifier, retro-actively coupled and having a tuned circuit so adjusted as to make the amplifier maintain oscillations at a frequency which is a multiple or a sub-multiple of the frequency of the signal to be received. This amplifier is followed by an audio-frequency amplifier having its transformer circuits sharply tuned to the beat frequency formed by the interaction of the signal and the locally generated oscillation. It is stated that the detection of the signal takes place before it is applied to the aperiodic amplifier.

Grid Control for Transmitting.

An interesting system of keying a transmitter, particularly suitable for a single-valve transmitter is shown in British Patent No. 205,878 (Preston and others, British). Broadly, according to the invention the grid coil is divided into one or more portions of which one portion is shunted by a variable condenser, and one portion may be short-circuited by a switch. A straightforward arrangement is shown in Fig. 4. The normal grid tuned circuit is formed by the inductance D and condenser E. The tuned circuit FGH is provided, the coil H of which may be short circuited by the switch P, which is electro-magnetically controlled by the key Q. The circuit FGH is tuned approximately to the same frequency as the other oscillatory circuits. In these circumstances the set will oscillate when the switch P, short-circuiting the coil H, is closed, and will stop oscillating when the switch is open. Another arrangement is shown

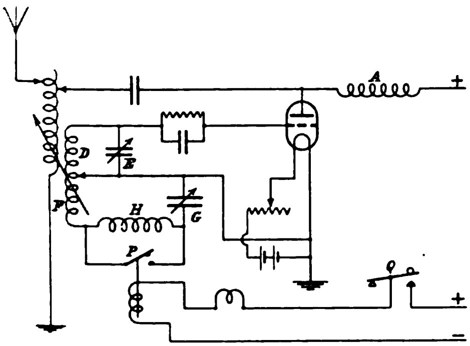


Fig. 4

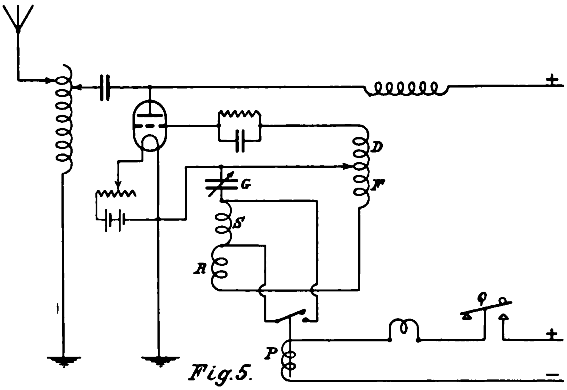


Fig. 5.

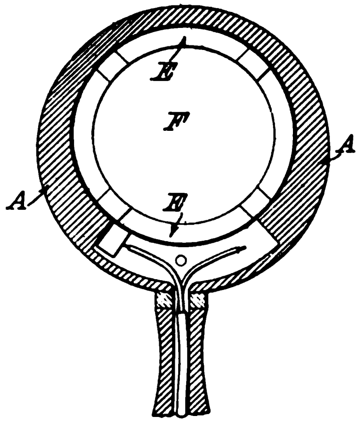


Fig.6

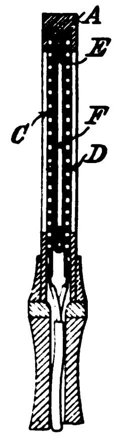


Fig.7.

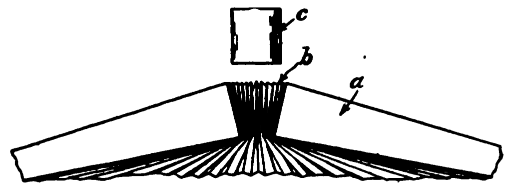


Fig.8.

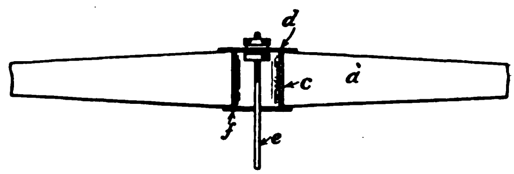


Fig.9.

in Fig. 5 wherein there is no electro-magnetic coupling between the grid circuit and the anode circuit. In this arrangement the coils S and R are mutually coupled and wound in opposite directions. The main principle of this invention seems to be the use of an absorption circuit associated with the grid circuit of a triode. It is stated that this method of control may be used for grid modulation for wireless telephony. Presumably for this purpose it would be necessary to insert a variable resistance device such as a carbon microphone in place of the switch P, or possibly across the whole of the inductance of the extra circuit.

Telephone Instruments.

The advent of broadcasting has brought a problem new to the radio engineer, and that is to produce both good transmission and reception of

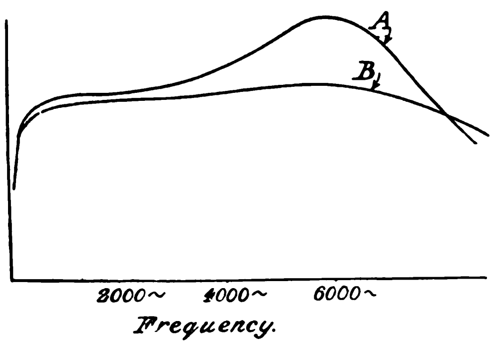


Fig.10.

speech and more particularly music. It is undoubtedly preferable that the reception end should employ a loud speaking telephone instead of head receivers. For many years the electro-magnetic receiver and resistance transmitter have been almost the only instruments used for telephony. With the modern demand for perfect reproduction of music and speech, as opposed to "commercially good enough" production, inventors have turned to a very old instrument known once as the "speaking condenser." The speaking condenser has many advantages when pure reproduction is the main desideratum. British Patent No. 206,601 (McLaughlin, British) describes a condenser which may be used either as a microphone or as a telephone receiver, when associated with suitable circuits.

A sheet of tissue paper is coated on one side with a film of metal and is placed against a perforated plate of metal which is coated with insulating varnish. Figs. 6 and 7 illustrate the construction of this instrument. The frame-ring of A of insulating material carries two metal plates C and D, one

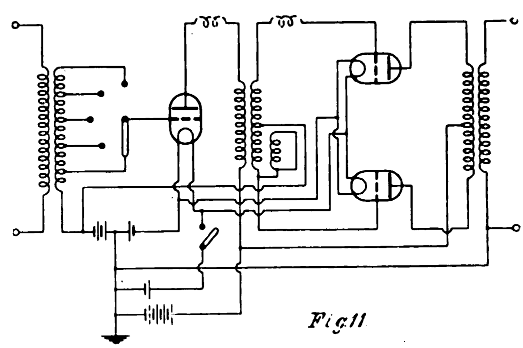


Fig.11

of which is coated with insulating varnish on its inside. The metal-coated tissue paper F is supported at its edge by a ring E.

The type of loud-speaking apparatus which has a large diaphragm and no horn has received some attention. British Patent No. 205,578 (The Gramophone Co. and others, British) describes an improvement on the now fairly well-known large pleated diaphragm, described in British Patent No. 11015 of 1909. The present patent is for a method of adequately straining the diaphragm by means of a core. To form the diaphragm a length

of paper is pleated closely, and then the ends joined to form a tube having axial pleats. Then one end of this tube is pushed down and the other end expanded until the result is a nearly flat pleated diaphragm. At the centre the pleats remain, but near the margin they are stretched out. According to the new patent, before flattening out the diaphragm a cylindrical core is inserted and thus the required stress is imparted to the diaphragm. The core may be made of several convolutions of paper stuck together. Figs. 8 and 9 show the arrangement and are self-explanatory. The provisional specification states that for a diaphragm with approximately 100 radiating pleats each of width 7-16th in., the width of the strip from which the diaphragm is made being 6¾ ins., the diameter of the cylindrical core may be about 7-16th in.

Audio-Frequency Transformers.

It is well known to most people that audio-frequency transformers give rise to some distortion of speech currents, and many efforts have been made to minimise this distortion. British Patent No. 202,262 (Western Electric Co., of American origin) shows a method of doing this. A transformer is so designed that the effective inductance resonates with the tube capacity at a frequency near the upper limit of audibility, thus accentuating the higher frequencies which are apt to be bye-passed by the stray shunt capacities. In this way an amplifier can be made having a response characteristic as shown at A in Fig. 10. In order to suppress the rather pronounced hump it is well known to connect a large resistance across the secondary and so load the transformer. According to this patent, however, a third winding is provided of a few turns and a correspondingly low resistance is used, thus obviating the troublesome and generally expensive high resistance. Alternatively this low resistance may be shunted across a few turns of the secondary winding itself. The effect upon the response characteristic is shown at B in Fig. 10. Alternatively the tertiary winding or portion of the secondary may be made of the required resistance and short circuited. A diaphragm of a "push-pull" amplifier incorporating this invention is shown in Fig. 11.

General Apparatus.

A variable condenser having a rather novel principle is described in British Patent No. 206,769 (of American origin). The condenser is of the mixed di-electric type, and depends for its variation on "laying down" one plate upon another insulated plate. Figs. 12 and 13 show one form of condenser. When the spindle is rotated in a clockwise direction the capacity is a minimum as shown in Fig. 12, when the spindle is rotated in an

Fig. 12.

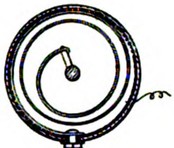


Fig. 13.

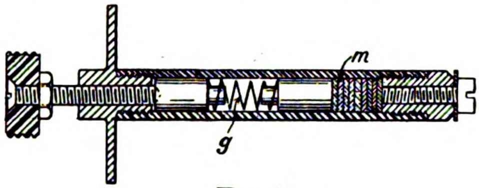


Fig. 14.

anti-clockwise direction the spiral plate is "laid down" upon the mica or like insulator covering the inner surface of the cylindrical plate, thus increasing the capacity. The same effect can be secured by a springy inside plate normally curling away from the outside plate and pressed towards the latter by a revolving shoe. The drawback of a condenser of this type is its usually large minimum capacity and losses. However, a condenser of a given maximum capacity can be easily and cheaply made in a smaller compass than can the usual vane type of condenser.

A patent for variable high resistances, such as grid-leaks, has just been published, namely No. 206,098 (Watkins, British). The construction described in the specification has a strong resemblance to the "Watmel" variable grid leak. The construction according to this specification is shown in Fig. 14. The discs or pellets M may be of fibrous material, for example cardboard or pâpier maché covered or impregnated with carbon or like material of low conductivity. Presumably our old friend, Indian ink, would be useful, perhaps combined with blotting paper. The compression spring G seems to be the essential feature. It seems as if a resistance of this type, while very useful for certain purposes, is not so valuable as might at first be thought. It would be expected to be somewhat unstable, and its resistance at a particular setting variable. However, in use in an experimental laboratory it is very valuable to have an infinitely variable high resistance, even if this is somewhat unstable.

Recent Wireless Publications.

Figures after the title of each publication indicate Volume and Number of Publication containing the article. Where only one number is given, this indicates the serial number of the publication. The abbreviations used in this bibliography will be found in th early issues of "Experimental Wireless."

I.—TRANSMISSION.

SOME POINTS ON TUBE TRANSMITTERS, PART I. H. F. Mason (*Q.S.T.*, 7, 4).

SOME POINTS ON TUBE TRANSMITTERS, PART II. —H. F. Mason (*Q.S.T.*, 7, 5).

A METHOD OF CONTINUOUS WAVE TRANSMISSION ON 100 METRES.—F. W. Dunmore (*W. Age*, 11, 2).

II.—RECEPTION.

THE SUPERDYNE RECEIVER.—C. D. Tuska (*Q.S.T.*, 7, 4).

TUNED RADIO FREQUENCY AMPLIFICATION.—A. L. Budlong (*Q.S.T.*, 7, 5).

A NEW NON-OSCILLATING DETECTOR (*Q.S.T.* 7, 5).

SHORT WAVE TUNER DESIGN.—K. E. Hassel (*Q.S.T.*, 7, 5).

A NEW AND ULTRA-SENSITIVE DETECTOR, THE SODION.—John V. L. Hogan (*Radio News*, 5, 6).

SOME NOTES ON RECEIVING ANTENNA RESISTANCE. —Samuel C. Miller (*W. Age*, 11, 2).

TUNED RADIO FREQUENCY AMPLIFICATION.—L. W. Bishop (*W. Age*, 11, 2).

MINERALS THAT ARE USED AS CRYSTAL DETECTORS. —Dr. E. Bade (*W. Age*, 11, 2).

A SUPERSONIC HETERODYNE RECEIVER.—W. S. Barrell (*W. World*, 223).

THE OPERATION OF THE ARMSTRONG SUPER.— D. F. Stedman (*W. World*, 223).

THE SUPERSONIC HETERODYNE RECEIVER.—W. S. Barrell (*W. World*) 224.

THE FUNDAMENTALS OF LOUD SPEAKER CONSTRUCTION.—A. Nyman (*W. World*, 226).

THE OPERATION OF THE ARMSTRONG SUPER (*W. World*, 226).

LOUD SPEAKERS.—E. Alexander (*Mod. W.*, 2, 3).

DISCUSSION ON LOUD SPEAKERS.—The Institution of Electrical Engineers with Physical Society (*Electn.*, 2377).

THE FADING OF RADIO SIGNALS.—Prof. G. W. O. Howe (*Electn.*, 2378).

III.—MEASUREMENT AND CALIBRATION.

MEASUREMENTS OF RADIO SIGNALS (*Q.S.T.*, 7, 4).

EIN EINFACHES KOMPENSATIONSVERFAHREN ZUR UNTERSUCHUNG VON KONDENSATOREN BEI NIEDEREN UND MITTLEREN FREQUENZEN.— Wilhelm Geyger (*Jahrb. d. drahtl. Tel.*, 22, 4).

THE WIEN BRIDGE.—A. Rosen, A.C.G.L., B.Sc., (*Phy. Soc. Lond. Proc.*, 35, 5).

V.—GENERAL.

VACUUM TUBE CHARACTERISTICS.—John H. Miller (*Q.S.T.*, 7, 4).

EFFECT OF GRID FILAMENT CONDUCTIVITY ON AMPLIFICATION.—F. M. Colebrook, B.Sc. (*Electn.*, 2375).

ELECTRONIC EMISSION (*Electn.*, 2378).

ZUR THEORIE DER AUSBREITUNG ELECTROMAGNETISCHER WELLEN AUF DER ERDKUGEL.—Otto Laporte (*Ann. d. Physik* 70, 8).

DIE HISTORISCHE ENTWICKLUNG DER ELEKRTONENRÖHRE IN DER DRAHTLOSEN TELEGRAPHIE.—Otto von Bronk (*Telefunken-Zeitung*, 32/33).

EINFLUSS DER ELEKTRONENEMISSION AUF DIE TEMPERATURVERTEILUNG GLÜHENDER WOLFRAMDRÄHTE IN ELEKTRONENRHÖREN.—Hans v Helms (*Telefunken-Zeitung*, 32/33).

ELECTRON EMISSION FROM THORIATED TUNGSTEN FILAMENTS.—Irving Langmuir (*Phys. Rev.*, 22, 4).

DIELECTRIC LOSSES AT RADIO FREQUENCIES IN LIQUID DIELECTRICS.—A. B. Bryan (*Phys. Rev.*, 22, 4).

MEASUREMENT OF MAGNETIC FIELDS OF MEDIUM STRENGTH BY MEANS OF A MAGNETRON.— Albert W. Hull (*Phys. Rev.* 22, 3).

POLARISATION CAPACITY AND RESISTANCE AT RADIO FREQUENCIES.—C. B. Jolliffe (*Phys. Rev.*, 22, 3).

REMOVAL OF THORIUM FROM THE SURFACE OF A THORIATED TUNGSTEN FILAMENT BY POSITIVE ION BOMBARDMENT.—K. H. Kingdon and Irving Langmuir (*Phys. Rev.*, 22, 2).

TORQUES AND FORCES BETWEEN SHORT CYLINDRICAL COILS CARRYING ALTERNATING CURRENTS OF RADIO FREQUENCY.—W. A. Parlin (*Phys. Rev.*, 22, 2).

THE TANTALUM HIGH-VOLTAGE RECTIFIER.— Harold L. Olesen (*Q.S.T.*, 7, 5).

RADIO VISION.—H. Gernsback (*Radio News*, 5, 6).

UNTERSUCHUNGEN ÜBER HOCHFREQUENZTELEPHONIE AUF STARKSTROMLEITUNGEN. E. Habann (*Jahrb. d. drahtl. Tel.*, 22, 4).

UBER DIE RICHTUNG ATMOSPHÄRISCHER STÖRUNGEN.—F. Schindelhauer (*Jahrb. d. drahtl. Tel.* 22, 4).

UBER EINE NEUE EMPFANGSANLAGE DER HAUPTFUNKSTELLE NORDDEICH.—G. Leithäuser (*Jahrb. d. drahtl. Tel.*, 22, 4).

DIE SCHWINGUNGSERZEUGUNG DURCH RÜCKKOPPLUNG VERMITTELS DER ANODEN-GITTERKAZITÄT BEI DER HOCHVAKUUMEINGITTERRÖHRE.—(*Zeitschr. f. tech. Phys.* 1923, 3).

METEOROLOGIE UND WELLENTELEGRAPHIE (*Zeitschr. für tech. Phys.* 1923, 3).

MAGNETISCHES MATERIAL FÜR HOCHFREQUENZFELDER.—Richard Gans (*Physikal. Zeitschr.*, 24, 11).

SEKUNDÄRE ELECTRONENEMISSION IN GLÜHKATHODENRÖHREN.—A. Goetz (*Physikal. Zeitschr.* 24, 2).

ZUR EXPERIMENTELLEN UNTERSUCHUNG VON TELEPHONEN (*Ann. d. Physik*, 70, 4).

METEOROLOGIE UND WELLENTELEGRAPHIE.— Friederich Herath (*Zeitschr. f. techn. Phys.*, 1923, 3.)

CHARACTERISTICS OF AIRPLANE ANTENNAS.—E Bellini (*W. Age*, 11, 2).

DISTORTION IN RADIO TELEPHONY (Concluded).— H. A. Thomas (*W. World*, 223).

VULCANISED FIBRE.—James Strachan (*W. World* 224).

LES ACCUMULATEURS : LEUR FONCTIONNNEMENT, LEUR ENTRETIEN, LEUR RECHARGE.—E. Pepin ster (*R. Elec.*, 4, 18).

Correspondence.

The Periodic Fading of Signals.

To the Editor of EXPERIMENTAL WIRELESS.

SIR,—I was very interested in Mr. Cash's observations on the regular fading of signals which is so frequently noticed. I have myself noticed this regular fading at times, although I have not made any careful observations on them. It is puzzling why there should be this regularity if one is to account for fading entirely by atmospheric conditions, which, as we know, do not follow any regular changes at equal intervals of only a few seconds or minutes. It is difficult to imagine weather travelling across the Atlantic in the form of a long procession of evenly-spaced lumps, and I think we must look for some other explanation. It has occurred to me that the periodic rising and falling of the strength of signals received from a distant station may be very reasonably explained by assuming that interference takes place between direct waves and waves reflected from the heaviside layer.

Suppose a receiving station B is listening to a distant transmitting station A on about 200 metres wave-length. The radiation from A goes out more or less uniformly in all directions, part travelling straight to B's aerial, and part arriving at B after reflection from the heaviside layer. B therefore receives signals from A *via* two distinct paths, and the amplitude of the oscillations induced on B's aerial will depend on whether the two sets of waves help or oppose each other at that point. If the path difference between the direct and reflected courses is equal to a whole number of wave-lengths, the two sets of waves will assist each other and produce a strong signal, whereas if the paths differ by an odd number of half wave-lengths the two sets of waves will tend to cancel and produce silence. As we go along the line adjoining A and B we come alternately to points where the direct and reflection paths of waves coming from A differ by equal and odd numbers of half wave-lengths. In fact, there are extending out from the transmitting station A alternate zones of maximum and minimum signal strength, the distance between successive zones depending on the wave-length, the effective height of the heaviside layer considered as a reflector, and the mean distances of the zones under consideration from the transmitting station.

So much has already been suggested, and was mentioned by Capt. Round at a recent meeting of the Radio Transmitters Society. The phenomenon of diffraction bands in the case of ordinary light has been familiar for a long time, and it is only reasonable to expect similar effects on a larger scale with radio waves.

My own little corollary is that we should take the earth's rotation into account. If the height of the heaviside layer were constant and the wave-length of a given transmitting station A were constant, then B would be permanently lucky or unlucky in his reception of A according to whether he was situated on a "dark" or "bright" zone. But the accepted theory is that the ionised layer has a much smaller effective height during the day than during the night. As night comes on it goes up, and when day approaches down it comes again. In fact the effective reflecting surface is probably on the move the whole time except just at the turning point a little after midnight. As the heaviside layer rises or falls, as the case may be, the whole set of interference bands or zones sweep along and pass one after the other through the receiving station B. As the velocity and spacing of the bands will be nearly uniform over short periods the operator at B will hear a regular swelling and fading of signals.

In trying to calculate the fading period for a given distance on this theory one is up against the difficulty of not knowing the height of the heaviside layer at various times duringt e day, or the rate at which it rises at night. Also, we are not justified in considering it a definite reflecting surface, as it is a layer of attenuated ionised gas probably many miles thick ; more probably the waves are deflected by successive refractions, the effect being more akin to inverted mirage rather than to reflection proper.

E. H. ROBINSON.

Vo the Editor of EHPERIMENTAL WIRELESS.

DEAR SIR,—After reading Mr. Hogg's letter in the current issue of EXPERIMENTAL WIRELESS, I should like to point out that Mr. Hogg's calculation of the effective height of his aerial is entirely erroneous. In his letter he assumes that the effective height of an aerial is its mean geometric height. This is by no means the case. In calculating the effective height of an aerial the following things must be taken into consideration :—

(1) The mean height of the aerial. (This is not the mean height of the flat top of the aerial minus the height of the counterpoise, as Mr. Hogg seems to think ; if so, why not lay the counterpoise along the ground ?)

(2) The effect on the aerial of surrounding trees, houses, etc. I feel compelled to point out this error in order to prevent your other readers from falling into the same trap as Mr. Hogg.—Yours faithfully,

M. C. ELLISON. (2JP)

To the Editor of EXPERIMENTAL WIRELESS.

DEAR SIR,—In reply to Mr. Ellison's letter regarding my aerial, I am fully aware of the facts which he has mentioned. I was only trying to point out that my report on the resistance was nowhere near 10 ohms. I believe that this is not far out in an amateur aerial to take the effective height as about two-thirds of the height above the counterpoise. I am afraid the misapprehension arose through my omitting the word "greater." I intended to say the effective height was not greater than 28 ft. so as to leave the exact effective height out of the question. Personally I consider myself lucky if my true effective height is 19 ft.! I shall not attempt to be absolutely

accurate, as such calculations are nowhere near correct, and merely serve as a very good guide.—Yours faithfully, FREDERICK L. HOGG.

To the Editor of EXPERIMENTAL WIRELESS.

DEAR SIR,—In your last issue of EXPERIMENTAL WIRELESS you publish an article by Mr. H. N. Ryan on the "General Efficiency of Reception on Short Waves." There are two points in this article on which I find myself in complete disagreement, and I should be very interested to hear what the author has to say on the matter.

(1) On p. 142, column 1, Mr. Ryan says the following:—"The universal fault with all short-wave plug-in coils on the market is that the wire used is far too thin. All coils for short-wave work should be wound at least 18 or 20 gauge wire. . ." I should like to ask him (A) how pure resistance enters into the matter at all, seeing that at such frequencies as those with which he is dealing the resistance of the coil is negligible compared with the inductance of the coil, *i.e.*, pLR? (B) If the pure resistance were a matter of concern, why has he entirely neglected the increase of resistance with frequency? If he were to use wire of gauge 19 at a wave-length of 200 metres the H.F. resistance of that wire would be 9·4 that of its D.C. or L.F. resistance; whereas if he used considerably finer wire this ratio would be very much less, and the D.C. resistance would not be increased in anything like the same proportion.

(2) On p. 141 at the foot, or rather near the end of column 1, the author states:—"Theoretically the signals heard in the 'phones are loudest and purest when the local oscillations . . . are of exactly the same amplitude as those produced by the received signals." I beg to differ on this point. One of the great points about heterodyne reception is that the resulting rectified current is proportional to the signal E.M.F. and *not* to the SQUARE of the signal E.M.F., as would be the case if the heterodyne method were not used. But in order to arrive at this direct proportionality the local oscillations must be very large compared with the signal. In the case of ordinary reception the signal E.M.F. oscillates about a small curved portion of the rectifier curve. In the case of heterodyne reception, the beat wave is no larger than the signal, E.M.F., but it is super-imposed upon the local oscillation, hence in the positive ½-cycles it works on the straight part of the characteristic, whereas in the negative it is carried beyond the point of zero current. Thus, in the former case the rectification depends on the curvature at P, and hence on the SQUARE of the signal E.M.F., and in the latter case on the SLOPE at Q, and by going one stage further it can quite easily be shown that the rectified current will then be approximately proportional to the signal E.M.F. But the whole point of this little discussion is, that in order to attain this desirable state of affairs the amplitude of the local oscillations must be sufficient to bring S_b on to the straight part of the rectifier curve when positive, and beyond the zero current position when negative. This state of affairs is *not* fulfilled when S_2 only $= S_1$. The only time when this state of affairs is desirable (*i.e.*, $S_2 = S_1$) is when advantage is being taken of the limiting action explained in the article by Capt. St. Clair-Finlay.

A few lines later on in his article Mr. Ryan goes on to say:—"Therefore, always try to keep the receiver only just oscillating for C.W. reception . . ." This is perfectly correct, and would at first sight seem to bear out his argument for small amplitude of local oscillations; but is the author aware that the point where the valve produces *maximum* amplitude of oscillations is that point at which the coupling between the grid and the anode is *least*, so long as the point where oscillation commences is not passed? I do not write this in any sense of undue criticism, but I believe the author to be *wrong* in the two cases I quote, and I have just given you a rough outline of *why* I think he is wrong. I should be glad if you would give Mr. Ryan the chance of replying to my criticisms, but I fear he will find he has made an error in the above, which may, unfortunately, be passed on to others.—Yours faithfully,

DESMOND DE BURGH.
(Flight-Lieut., R.A.F.)

To the Editor of EXPERIMENTAL WIRELESS.

DEAR SIR,—May I point out the article in question was based entirely upon practical experience, and sets forth the results obtained in practice. Therefore, I should have advocated the same principles, even had I felt them to be the wrong in theory. This, however, was not the case, and I cannot agree with all Mr. de Burgh's criticisms.

Firstly, he says that at high frequencies the necessity for using thick wire does not arise, since resistance is negligible, compared with inductance. Quite apart from theory, it is an experimental fact, established beyond question, that thick wire gives greatly improved results on short waves.

It is evident that, when receiving weak signals, every possible loss should be minimised. Now, the inductance of a coil at this frequency admittedly greatly exceeds its resistance, but no loss of energy is occasioned by pure inductance, whereas the chief source of loss in an inductance is due to its resistance.

I am afraid I fail to see his next point. He states that the ration of H.F. to D.C. resistance is less in a thin wire than in a thick one, of which elementary fact I was aware, but he is apparently trying to deduce from this that the H.F. resistance of a thin wire is less than that of a thick one, which can be shown to be incorrect by a simple measurement.

But whether Mr. de Burgh agrees with this or not, I made no mention whatever, in the article, of resistance, pure or H.F.

Now for the other point, which presents much more interest. Firstly, I do not agree that, in practice at any rate, the valve is producing maximum amplitude of oscillation when the coupling is just at oscillation point. When the plate and grid circuits of a valve are coupled and are not in resonance (*i.e.*, when the one with the higher natural frequency is functioning aperiodically, in our case the plate circuit) the point of maximum amplitude of oscillation appears to be with the coupling somewhat tighter than the critical value, approaching this critical value as the circuits are brought nearer to resonance. In an ordinary

receiver of non-American design the plate coil is usually aperiodic, and therefore falls within this class.

I should not care dogmatically to state the foregoing effect, but it appears thus to me.

As to the question of strong or weak local oscillations, apart from how they are produced, I agree entirely with the case for strong oscillations as far as it goes, but though the effect in question is one of the most valuable points of heterodyne reception *for signals above a certain strength* there is a certain strength (admittedly a pretty weak, though far from unreadable, one) below which the effect cannot be utilised. The reason, I think, is that when the signals are very weak the strength of heterodyne required to bring the working point for +ve half-cycles) on to the straight part of the curve is so great compared with the signal amplitude (*i.e.* $S_2 > S_1$) that the latter is completely wiped out, since the circuit will not oscillate at two frequencies very close together, when the amplitude of one is very much greater than the other. So one must either work on the bend (where $r \propto e^2$), or lose the signal.

Since, apart from this effect, the beat note reaches its maximum when $S_1 = S_2$ (the maximum being $S\beta = (S_2 + S_1) - (S_2 - S_1) = 2S_1$ there is no useful object in increasing S_2 beyond S_1, when the incoming signals are too weak to take advantage of the further boosting without losing themselves in the process.

To the fatal effects of too strong a heterodyne, in practice, on very weak signals, I can testify, as can many others.

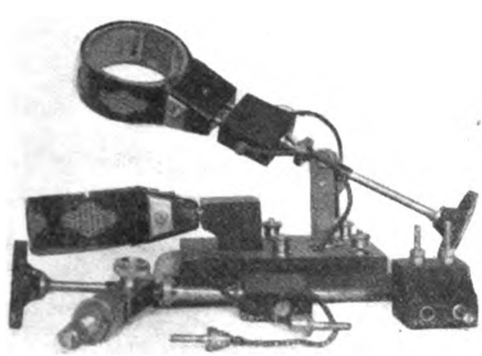
The explanation I put forward as a suggestion only. There obviously must be some point of critical strength such as I suggest. The indication of the suggestion turns upon whether this point falls within or without the range of readability. I personally think it falls well within it, though, of course, fairly near the lower limit. The article dealt professedly only with weak signals, and I stated that a receiver built on the lines suggested would not work at its best on strong signals, nor would it be required to do so.

I may say that a receiver of my own, on these lines, receives American amateurs and broadcast easily on a single valve, so I do not think, therefore, that anyone making one like it will have cause to complain of having been lead astray by my advice, as Mr. de Burgh seems to fear!—Yours faithfully,

HUGH N. RYAN (5BV).

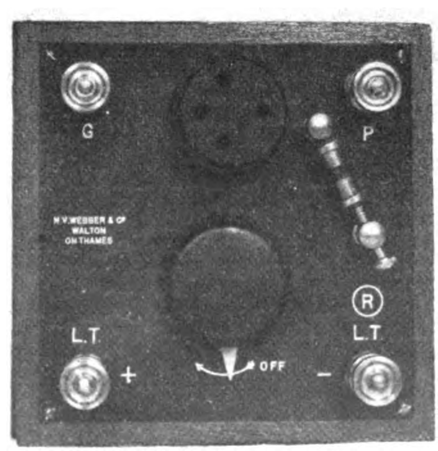
Business Brevities.

A NEW "POLAR" COIL HOLDER.—The Radio Communication Co., Ltd., have sent us for test a new type of coil-holder which embodies several really new and useful improvements. The movable coil support is perhaps best described as representing an anti-aircraft gun. On test it is found to give the most flexible adjustment of any type we have so far examined, since there are four possible directions of motion. It is obvious that any degree



The New Polar Coil Holder.

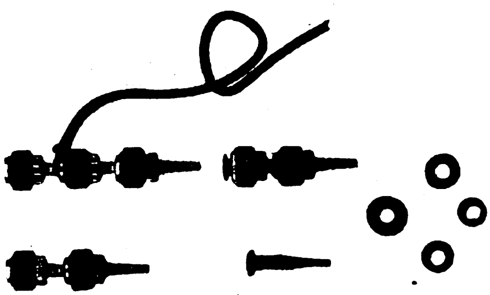
of coupling is obtainable, including direct and reverse retro-active effects, and also, of course, an easy adjustment of capacitative and magnetic coupling is easily obtainable. The holder is supplied both for panel mounting and as a complete unit with terminals.



The Webber Experimental Panel.

THE WEBBER VALVE PANEL.—It might seem at first sight somewhat unnecessary to mention so common a component as a valve panel, but that

sent for test by N. V. Webber & Co. should appeal particularly to the serious experimenter, as it contains several refinements. The four terminals are of the large size double-type, enabling several



Illustrating some uses of "Clix."

wires to be fixed to each. The filament lead containing the rheostat is marked on the top of the panel, and a Polar fuse is included in the filament circuit. The above features in conjunction with an Igranic rheostat make the panel of particular value for experimental work.

"Clix."—"Clix," described as the "electrical link" with 159 uses, is one of the most useful "gadgets" which have been brought to our notice. Essentially, "Clix" are wander plugs, so made that the tapered end of one will fit into the socket end of another. The insulating tops may be removed and replaced by two bushes so as to enable them to be used as sockets on a panel top. "Clix" appear to be both mechanically and electrically efficient, and there is no doubt that they will be of very great value for experimental work requiring rapid and complex variations of connections. "Clix" have been produced by Autoveyors, Ltd.

* * *

Messrs. S. Rentell & Co., Ltd., have sent us the 1924 edition of their well-known "Practical Electrician's Pocket Book." This useful little book contains some 500 pages crammed with practical information and data, and should be of value to many readers. The price is 3s. net.

* * *

Messrs. Autoveyors, Ltd., have sent us their latest pamphlet relating to their capacity bridge. The booklet contains 15 pages of useful bridge circuits which should be of interest to the experimenter.

Experimental Notes and News.

It is understood that the Post Office has placed contracts in this country for the equipment of several new stations to operate between the various islands in the West Indies, including St. Kitts, Antigua, Barbados, Dominica, St. Lucia, St. Vincent, and Grenada. It will be interesting to see what wave-lengths are adopted, for the seven stations are comparatively within a very small area.

* * *

Although some excellent DX work is now being conducted by many experimenters, so far no one seems to have succeeded in communicating with the MacMillan American Arctic Expedition. It is understood, however, that several American amateur stations have been in touch with the ship, and there seems no reason why our own stations should not be able to maintain communication.

* * *

The Metropolitan-Vickers Electrical Company are making their first attempt on New Year's Eve to pick up the American Broadcasting Station "KDKA," and re-transmit it on 400 metres from Manchester. They will use $1\frac{1}{2}$ kilowatts and the call sign will be 2AC.

It will be interesting to note what effect the broadening of the band of wave-lengths used by the British Broadcasting Stations will have upon jamming. The problem presents many difficulties, as the new wave-lengths seem, in some cases, to be affected by ship work, D.F. stations and harmonics. At the time of going to press the wave-lengths now adopted are as follows :—

495	Aberdeen.	385	Bournemouth.
475	Birmingham.	370	Newcastle.
435	Cardiff.	350	London.
420	Glasgow.	303	Sheffield (Relay).
400	Manchester.		

* * *

The Radio Association has decided to organise a National Radio Week next year. The main objects will be to demonstrate the growth of a new British industry, and to arouse interest in the possibility of broadcasting among all sections of the community.

Experimental Wireless

A JOURNAL OF RADIO RESEARCH AND PROGRESS

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Experimental Topics.

An Amateurs' Radio Research Fund.

IT is a pleasing thing to find the attention of a wireless club being occasionally devoted to the general advancement of radio science as a change from the individual problems and requirements of their own members. The Derby Wireless Club, at their annual general meeting—their thirteenth A.G.M. by the way—discussed the possibility of forming an Amateurs' Radio Research Fund. The proposal made was that all holders of wireless licences should be invited to contribute to such a fund, a minimum subscription of one shilling being suggested, and that the revenue be devoted to research. Radio television was advocated as being a suitable li e of investigation, but it was thought that the nomination of the precise subject and of an expert investigator might be left in the hands of the President and Vice-Presidents of the Radio Society of Great Britain. Here is the germ of a good idea. It is very appropriate that those who benefit by the wireless facilities now available should do something practical to advance further discovery. Donors to the fund would get a direct return in the greater service which improved wireless could render them, and incidentally they would have the satisfaction of knowing that they were contributing to the advancement of a branch of science in which they were personally interested. The precise method by which such a fund might be most usefully employed needs, we think, fuller consideration and discussion. A great deal of research work is already being conducted in university and college laboratories, as well as by private workers, and possibly some portion of the amount subscribed might be employed with advantage in founding research scholarships, or in some other way subsidising the work of qualified student or staff workers in those institutions. The founding of an annual prize for the best piece of private research work might be another useful means of encouragement of effort. It is not always the professional investigator who makes the most important discoveries in science, and the possibility of securing some adequate recognition of their work might encourage amateur experimenters not only to greater effort, but to conduct and record their experiments in a more systematic way. In any case, the Derby proposal is an interesting one, and we shall be glad to open our columns to any of our readers who would like to express their views.

The Transatlantic Tests.

The annual Transatlantic tests have always been regarded as one of the most important events in the life of the amateur transmitting enthusiast, or "ham," as he is familiarly termed in the States. Perhaps it is safe to suggest that in the light of the success of this year's performance, low-power Transatlantic communication will be so commonplace that in the very near future any organised tests will cease to exist.

There is even now very good evidence that this is likely to be the case, for although the official tests have been concluded, almost regular Transatlantic communication is still continuing. Future development is likely to occur in two directions. Up to the present time Transatlantic work has been confined to the winter months, roughly from November to April. This year, however, the first results were obtained as early as August, and there is every indication that experimenters will be carrying on well into the late spring. The next step will be two-way telephony. Already speech has been received from America and British 2KF is reported as having been heard, but not confirmed. The reason for the increasing success of each year's performance is not very obscure. It is obviously due to the greater experience and knowledge of the experimenter, to whom we offer our heartiest congratulations, and we hope that he will achieve even greater things during the present year. In the later pages of this issue will be found very full details of some of the apparatus and circuits which were specially designed by some of the most successful experimenters for this season's tests.

Dealer and Experimenter.

Does the dealer stock components which the experimenter really requires? Recently we had need to purchase rather hurriedly so simple an item as a single-pole three-point switch, and were forced to visit no fewer than seven dealers before the desired switch could be obtained. In addition, only one shop was capable of delivering from stock three non-inductive resistance, and of these only two were of the same value. Such an experience as this prompts us to criticise the average dealer's selection of components and apparatus. True, there seems to be an everlasting demand for crystal detectors, variometers, inter-valve transformers, and other joys for the home constructor, and it is only natural that these should predominate on the shelves and in the show-cases of the " wireless shops." On the other hand, there is a very considerable number of experimenters who demand an entirely different class of goods. The genuine experimenter is at heart a scientist and conducts his investigations in a true scientific manner. Accordingly he requires a high-class instrument of guaranteed accuracy on which he knows he can depend. Losses must be reduced to a minimum, insulation must be perfect, operation must be constant, and efficiency a maximum. Condensers, inductances, resistances, meters, and switching devices which conform to these requirements should find a ready market. We know that they exist, but if some of our enterprising dealers could give a little more prominence to them and study a little more carefully the tastes of the experimenter, we feel sure that it would be to their advantage. The experimenter is usually a good customer, and is prepared to pay a reasonable price for really good apparatus.

An Institution of Wireless Engineers.

One of our contemporaries, in an editorial comment, asks how long will it be before this country rises to the dignity of having an Institution of Wireless Engineers, and points out how divided and scattered are those connected with radio engineering. Of course, we have the wireless section of the Institution of Electrical Engineers, but such a body is obviously not in a position to devote sufficient time which the subject really demands. Admittedly the formation of an Institution and the definition of the qualifications for membership at once presents considerable difficulties, but all these would ultimately find some solution, and it is to be hoped that some very definite steps will be taken before very long to bring together our leading radio engineers and scientists.

"E.W.'s" Progress.

We desire to thank many correspondents for the complimentary references to EXPERIMENTAL WIRELESS in their letters. In our first number we pointed out that the scope of our activities would become more manifest issue by issue, and a glance over the 300 or more pages of matter which we have given during the past five months will show that our promise to give the experimenter some matter of first-class technical interets has not been unfulfilled. Every day brings further evidence of the importance of experimental work in the wireless field. We shall continue to keep our readers fully abreast of all new developments, both at home and abroad, and shall hope to deserve in the future as many kind messages of encouragement and appreciation as we have received in the past.

Post Office Radio Station, Devizes.

By J. H. REYNER, B.Sc., A.C.G.I.

DEVIZES is the Post Office station which deals with long-distance ship traffic. The ordinary stations are equipped with 1½ to 5-kw. spark transmitters operating on 600 metres, and are capable of working ships at ranges of from 150-300 miles, depending on conditions.

In August, 1920, however, a service was inaugurated, working on 2,100 metres C.W.,

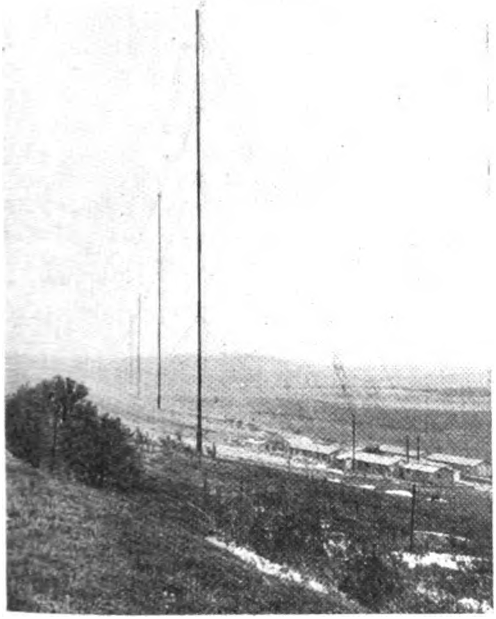


Fig. 1.—A general view of GKU.

for the purpose of maintaining communication with the large Transatlantic and south-bound liners, at considerably greater distances. The chief ships operating on these long-distance routes were accordingly fitted with 1½-kw. valve transmitters and the necessary C.W. receiving gear, while Devizes, which was chosen for the shore station, was equipped with a 6-kw. valve set. Since that time the number of ships fitted with C.W. apparatus has increased enormously, and there are several 3-kw. valve and 5-kw. arc sets in operation.

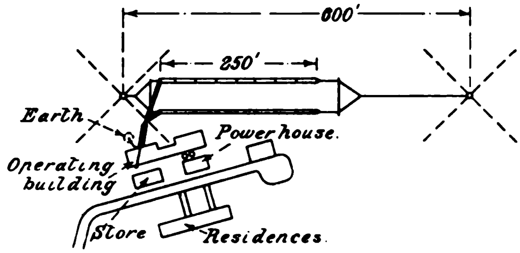


Fig. 2.—Layout of aerial system and buildings.

The Devizes station (GKU) is situated in the middle of the Wiltshire downs, about four miles from Devizes itself, on the Marlborough Road. Fig. 1 shows a view of the station looking east.

The first two masts only are in use at the present time. These two masts are each 300 ft. tubular steel masts of the Marconi pattern and are 600 ft. apart

The aerial is a double cage, 250 ft. long, each cage consisting of three wires spaced equally round a hoop 3 ft. in diameter. The lead-in is a 6-wire cage, 4 ft. 6 ins. diameter.

Fig. 2 gives a plan of the aerial system and the station buildings.

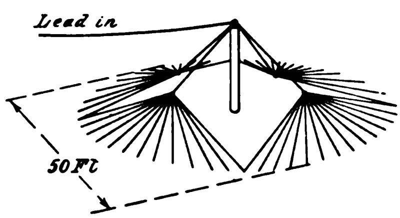


Fig. 3.—The earth system.

The earth system consists of 56 plates, 6 ft. by 2 ft. 6 ins. by 24 S.W.G. copper, buried in the earth on the circumference of a circle 50 ft. in diameter. The connections from these plates are collected in four groups and led to a common terminal at the top of a

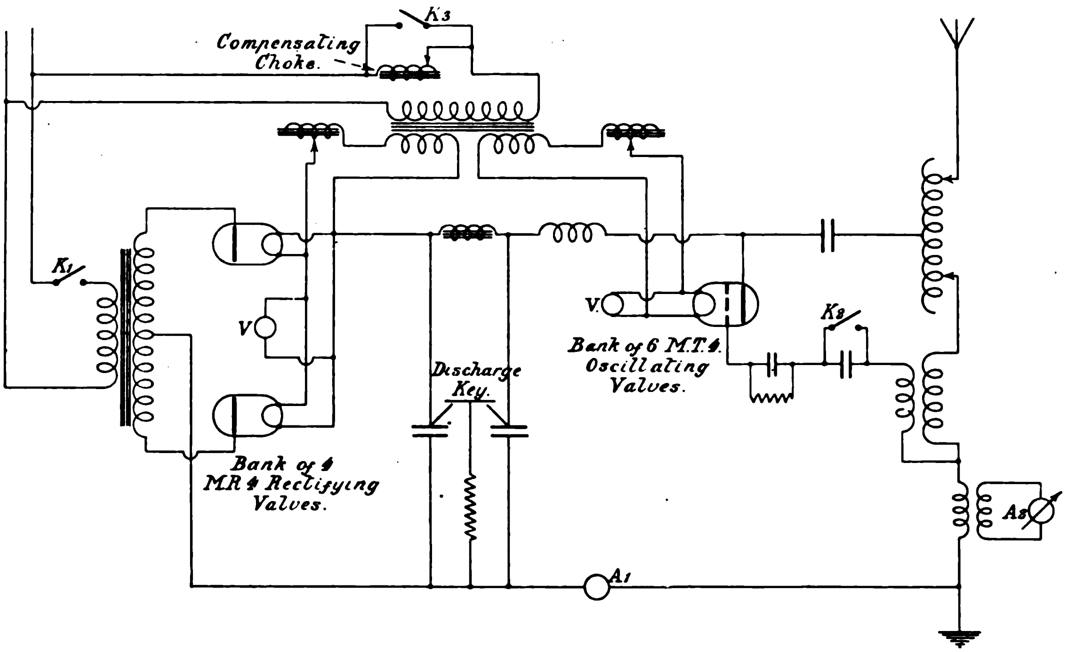


Fig. 4.—A simplified circuit diagram. The three keys are operated simultaneously.

10-ft. pole, whence a lead is taken into the operating building.

Fig. 3 gives a diagram of the earth system.

Transmitter.

The transmitter is a Marconi 6-kw. valve set employing six M.T.4 oscillating valves

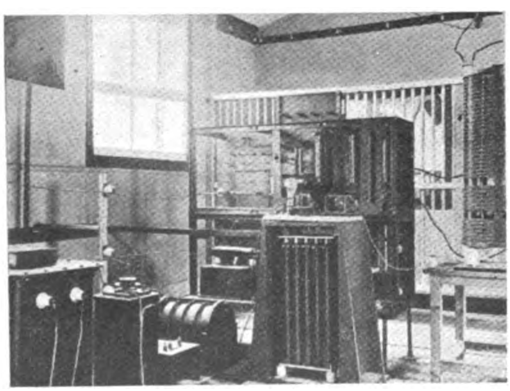


Fig. 5.—Back view of the panel.

and four M.R.4 rectifying valves. A simplified circuit diagram is given in Fig. 4. Power is supplied to the set at 500 volts 300 cycles, and is stepped up to 15,000 volts before being applied to the rectifying valves, which thus supply H.T. to the oscillating valves at about 10,000 volts D.C. The ripple on the rectified H.T. supply is smoothed by two condensers of ·25 μF operating in conjunction with a choke coil, as indicated.

The valve filaments are supplied from a stepdown transformer having two secondaries one supplying the rectifiers and the other the oscillators. By this means independent control is obtained, variable choke coils being inserted in each circuit to control the voltage applied to the valves. It should be noted that the valves are run at constant voltage as this is found to give a considerably longer life than with constant current working.

The oscillating circuit is of the direct-coupled type, the aerial constituting the tuned circuit, and an untuned reaction coil being connected in the grid circuit. A_1 is the feed ammeter, and A2 is the aerial ammeter operated through an air core transformer.

The parallel H.T. connection is employed as is usually the case for medium and high power sets, a high-frequency choke coil being inserted in the H.T. supply lead to keep the high-frequency currents from flow-

ing back through the transformer. A condenser is also placed in the anode tap lead, as otherwise the H.T. would have a direct short circuit path through the A.T.I. to earth.

Keying is effected by several electromagnetic keys, marked K_1, K_2 and K_3 in Fig. 4. These keys are normally open and are closed simultaneously by the depression of the operating key.

K_1 makes or breaks the primary circuit of the main transformer. K_2 controls the grid circuit, simply serving to disconnect the grid reaction coil when the key is up. As the H.T. supply is disconnected simultaneously there is no possibility of "grid tick." K_3 controls the compensating choke. When the load comes on the set the voltage drops slightly. To compensate for this a choke is inserted in the primary of the filament transformer which is short-circuited by the depression of the key, so increasing the voltage on the filaments sufficiently to make up for the drop in alternator voltage.

Fig. 5 gives a view of the back of the panel. The main and filament transformers can be seen on the left, while the A.T.I. is on the extreme right.

The aerial current is 20 amperes, the aerial resistance being of the order of 4 ohms, so that the actual high-frequency energy is about $1\frac{1}{2}$ kw.

Power Plant.

All the necessary power is generated on the station itself. There are two 16-kw. direct-coupled generating sets supplying D.C. at 110 volts. The engines are Robey semi-diesel type, running off crude oil. The sets are run on alternate days and normally charge a 450-amp.-hour battery, which supplies the station for the remainder of the day, although arrangements can be made in case of emergency to eliminate the battery. Figs. 6 and 7 give views of the generating plant and switchboard.

Lighting for the station is run direct off the battery. The power for the set, however, is supplied through a motor alternator converting to A.C. at 500 volts 300 cycles. There are two such machines (one standby) housed in the apparatus room with the valve panel; this room also contains a motor generator set and distribution board for charging the filament batteries for the receiver.

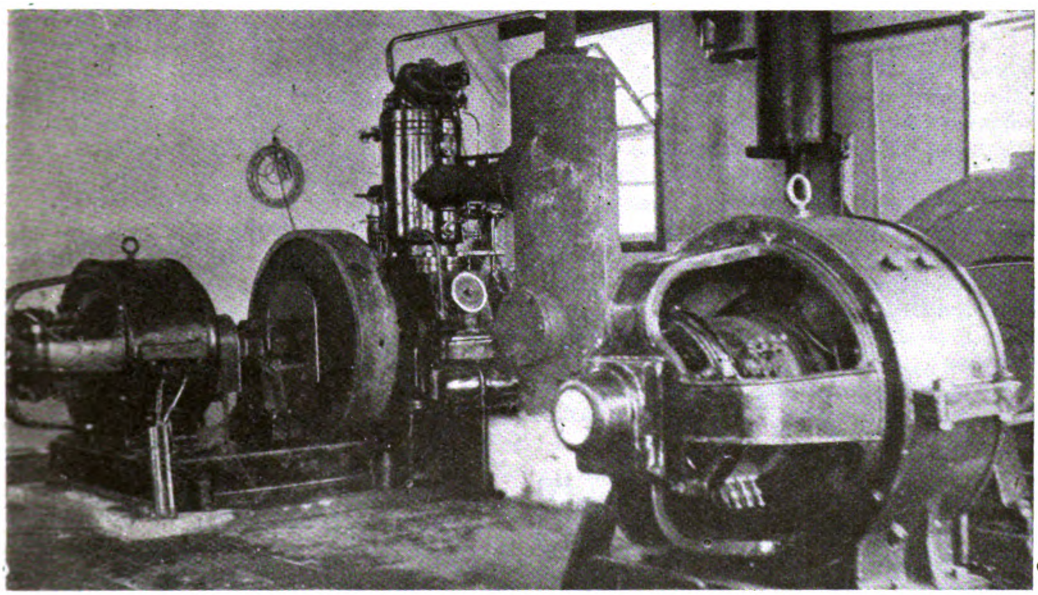


Fig. 6.—A general view of the generator plant.

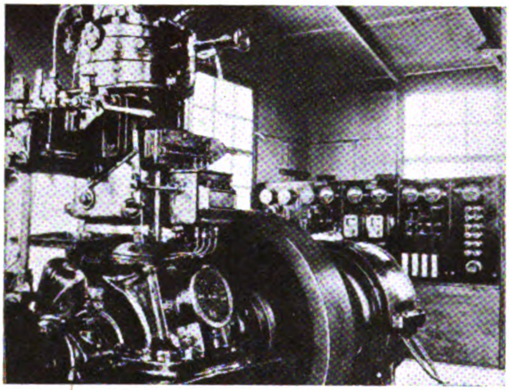


Fig. 7.—Generator with switchboard in rear.

Receiving Gear.

The receiving apparatus is shown in Fig. 8. It consists of a Bellini Tosi radio-goniometer, the signals from which are passed through a two-stage H.F. filter, amplified and rectified on a Marconi type 55 amplifier, and finally passed, if conditions permit, through a two-stage note filter. One or two extra stages of (low-frequency) magnification are available if required.

The note filter can only be employed on steady notes. In a heavy sea the ships are inclined to roll, and this, by altering the aerial capacity, causes considerable variations in wave-length. Modern transmitters, however, are fitted with coupled circuits or master oscillators, so rendering the wave-length independent of the aerial capacity.

Fig. 8.—The receiver and operating room.

Since most of the reception is from the west and south-west, the radio-goniometer is extremely useful, enabling "barrage" reception to be employed. For this arrangement a combination of frame and aerial reception is employed, the frame assisting the aerial in one direction but opposing it in the other. Hence, by suitable adjustment, reception from one direction can be suppressed over an arc of about 120 degs., which, of course, considerably minimises jamming, which very largely comes from the east.

The two aerials for the radio-goniometer are erected from the main mast, and are in the form of double triangular loops of 150 ft. side, as indicated in Fig. 9.

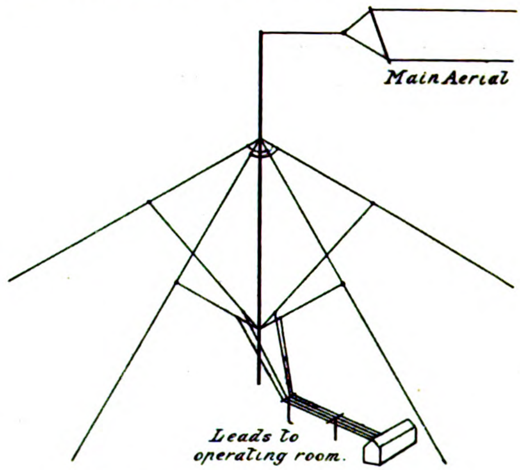


Fig. 9.—Arrangement of Bellini Tosi aerial.

All operating is done from the room shown in Fig. 8. The necessary switches and key are arranged close at hand and operate the transmitter by remote control. The valve panel itself is in the next room and can be seen through the glass panel on the left of the operator. The land line instruments are not visible in Fig. 8, but are situated in a separate compartment on the right. The table on the left of the figure contains recording gear for use when conditions permit of high-speed reception.

Since its inception the traffic handled by the station has increased enormously, and it is proposed to instal a second transmitter at Devizes and to remove the reception point elsewhere, so enabling duplex working to be carried out with both transmitters by remote control from the receiving station.

Directive Radio Telegraphy and Telephony.

BY R. L. SMITH-ROSE, Ph.D., M.Sc., D.I.C., A.M.I.E.E.

II.—DIRECTIONAL WIRELESS ON WAVE-LENGTHS ABOVE 100 METERS.

(*Continued from page* 198.)

During the last few years there has been considerable development in directional work, particularly with the use of extra short waves. There are obviously many applications of directional transmission, and we are giving below a general summary of modern methods and practice.

(g) Permanent Errors and their Causes.

If the conditions of the arriving wave are suitable for correct indication of direction by the rotating frame any local cause tending to distort the wave will result in an error in the observed direction. For example, if another receiver, whether of the closed coil or open aerial type, is in the neighbourhood of the direction-finder and tuned to the same incoming wave the direction-finder will be subject to both the original field due to the wave and a second field arising either by induction or re-radiation from the currents in the second receiver also due to the incoming wave. The effect of the superposition of this second field is easily observed in the form of an error in the reading of the direction-finder, except in the particular case when the two fields are coincident in direction.

For example, when a direction-finder is used within a distance of about 100 yards from a medium-size aerial and tuned to the same wave-length an error of 4° to 5° has been observed, and this would, undoubtedly, be greatly exceeded for a much larger aerial. A second frame coil brought within 30 ft. of the direction-finder introduces an error of the same order of magnitude. It is usually found that the detuning of the second aerial or coil circuit results in a large reduction of the error, which is then only appreciable at comparatively short distances. In many respects a tall tree is similar to an untuned vertical aerial, and, as would be expected, the effects on a direction-finder in the two cases are very similar. When, however, large numbers of trees are massed together in clumps their combined effects may be much larger, and it is found necessary to be at least one or two hundred yards from such clumps of trees in order to be free from directional errors, which at shorter distances may rise to 10°.

In the neighbourhood of a long run of a number of overhead wires, such as are frequently met with on a trunk telephone route, the errors are even more serious, and may amount to as much as 90°. The error in this case, however, decreases very rapidly with distance, and a movement of the direction-finder to about 100 yards from the wires is found to practically clear this error. In some cases the errors encountered in the neighbourhood of trunk telephone lines are observed to be subject to large variations of the order of 50°, due, possibly, to an alteration in the telephone circuit conditions.

Large masses of sheet or solid metal work in the neighbourhood of a direction-finder will have currents set up in them by the incoming waves, and the secondary field from these currents may cause an error in apparent direction of the waves, the error varying with the magnitude and distance of the metal work. Small tinned-iron boxes about 2 feet cube, for instance, produce errors of a degree or two when within 5 ft. of a frame coil direction-finder, whereas a large mass of ironwork, like an airship shed, produces errors ranging up to about 30° at points both inside and outside the shed. From the latter examples it would be expected the metal hull of a ship would produce errors in the reading of a direction-finding installation erected on board. This is found to be the case, the error in the observed bearing varying with the direction of the incoming waves relative to the ship's axis, giving a quadrantal error curve of the form shown in Fig. 9, which is a curve plotted

from some of the writer's observations. Unfortunately it is not possible to get far away from the disturbing metal work when using a direction-finder on board a ship, and some means must, therefore, be found of compensating for or correcting the error introduced. In many instances the stays, funnels, etc., contribute largely to this error on board ship, and where the wires form closed loops, with loose shackle joints, the conductivity of these may vary with the state of the weather from day to day, and the resulting error, therefore, becomes very variable. By taking suitable precautions, however, the error may be made fairly constant, and then the curve such as in Fig. 9, determined by tests made on stations in known distances, may be used as a means of applying corrections. Alternatively, means have been devised by which the constants of the circuits are adjusted so that practically complete compensation for the error can be obtained. Similar quadrantal error curves are obtained for direction-finders used on aircraft, although these are usually somewhat less in magnitude than a ship's curve. Here, again, difficulty is frequently experienced from the variability of the error due to variations in resistance of loops formed by wire stays, etc., and all

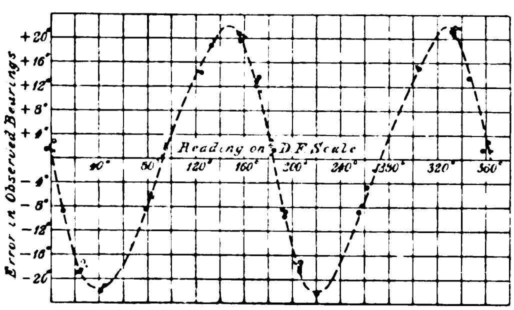


Fig. 9—Typical calibration of a wireless D.F. on board ship.

metal joints are preferably to be well bonded to maintain permanence of the error. Auxiliary coils may be mounted in the machine to introduce a third component into the field linking the direction-finder, which is adjusted to compensate, as far as possible, the second field due to the machine itself. Capacity effects between the machine and ground also frequently preclude the possibility of plotting an error curve obtained on the ground for use when the machine is in flight.

The characteristic shape of the quadrantal error curve produced by a long mass of metal work, like a ship, has led to at least one instance of the location of underground metal work by wireless direction-finding. A direction-finding set was erected for experimental purposes on a site which appeared to be perfectly satisfactory from the point of view of buildings, trees, telephone wires or other disturbing features above the surface. The bearings observed on the set, however, were found to be seriously in error in many cases, the error varying with the direction of the station observed. After many confirmatory observations, the error curve shown in Fig. 10 was plotted, and was found to be independent of any daily or seasonal variations. Now, in the case of Fig. 9, showing the error curve for a ship, the readings 0° and 180° on the direction-finder coincide with the fore and aft line of the ship. From the similarity of the two curves in Figs. 9 and 10 it seemed logical to conclude that the latter was produced by a large mass of metal work extending in a direction about 165° from true north. Examination of the site of the D.F. installation showed that this direction coincided with that of a large sewer, located by a line of manholes in the vicinity. Detailed exploration of the site with a portable D.F. set also showed the error to be definitely associated with the line of the sewer, correct readings being obtained at a distance of 100 yards from it. Reference to the surveyor's plans of the neighbourhood showed these deductions to be correct, for although the sewer itself was of non-metallic construction, a special length of it in the neighbourhood of these experiments was supported on a plate of steel, 300 ft. long by 6 ft. wide, this plate being about 8 ft. below the ground surface. In a similar manner it would be expected that gas and water mains or streaks of metal ore in the ground would produce errors on a direction-finder in the neighbourhood.

Owing to the varying conductivity of different portions of the earth's surface, it would be expected that waves might be subjected to a refraction effect. For ordinary cases of conductivity of dry land and sea-water this refraction is found to be only

appreciable when using waves shorter than 1,000 metres. The effect is such that in crossing the boundary from a material of high to one of lower conductivity the waves are bent towards the normal to the surface. As in the case of light, the deviation increases with the angle of incidence, and is greatest for grazing incidence at the boundary. The error experienced on a direction-finder from this cause is usually only a few degrees, although cases are quoted where it may reach 10°. Fortunately, the error is reasonably constant, and, when known, may be included in the corrections to be made to the readings of the instruments.

(h) Variable Errors.

From the preceding section it will be gathered that it is by no means an easy matter to find a site for a direction-finding installation which approaches at all closely to the ideal. In the light of experience gained in the investigation of errors it is, however, possible in many cases to select a fairly satisfactory site, usually in a very desolate part of the country at which the local errors encountered are reasonably small, *e.g.*, not greater than 2° or 3°. Having selected such a position, a calibration may be carried out, using either various permanent transmitting stations if these are well distributed around the points of the compass, or preferably a portable transmitter from which signals can be sent in various directions to the D.F. receiver. From this calibration a table or curve of corrections is made from which bearings taken in practical working may be corrected, depending upon the cause of these local errors, they may be quite permanent or slightly variable, and in any case it is advisable to repeat the calibration at moderately frequent intervals to ascertain any alterations that may be required in the applied corrections.

When a direction-finder is set up and calibrated in this manner, and used for observation on transmitting stations at reasonably short distances, it is found that the bearings obtained are extremely good on the whole, but are occasionally subject to slight variations which cannot always be attributed to an error of observation of the instrument. These variations, however, have an extreme amplitude of only 2° or 3°, and with highly skilled observers they rarely, if ever, give rise to an error in bearing exceeding 2°. Such a limit of accuracy is usually sufficient for most practical applications of direction-finding.

When the distance between the transmitter and receiver is increased, however, another and much more serious class of variable error enters the field, chiefly during the hours of darkness, and presents many more difficulties in the way of its compensation or elimination. The minimum distance at which this error is encountered in practice

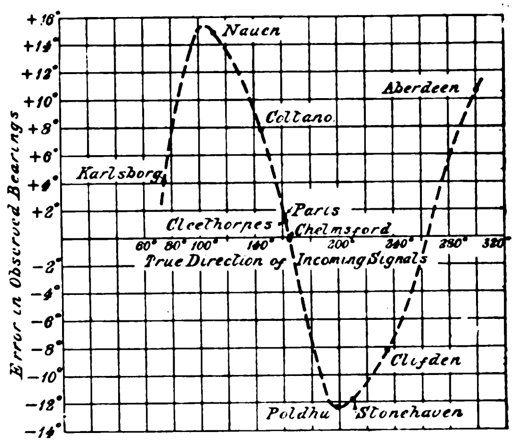


Fig. 10—Curve showing permanent deviations in bearings at Aberdeen University D.F. Station.

is found to be much greater over sea than over land, being roughly 90 miles in the former and 15 miles in the latter case. If the distance of transmission be gradually increased during observation the first sign that these variable errors are about to be encountered is given by a change in character of the signal minimum by the location of which the direction is determined. In place of the sharp, well-defined minimum or zero which is observed at short distances, a distinctly flattened or blurred minimum is obtained which often makes it extremely difficult to locate the true minimum point with any accuracy. As the distance is still further increased this blurring not only becomes a much more frequent occurrence, but the position of the minimum is also found to be very different from its true bearing position. The variable errors arising in this way do not usually occur when daylight prevails over the whole path of the transmission. In the neighbourhood of sun-

set at either the transmitter or receiver these variations are liable to commence, and they continue throughout the night until a short time after sunrise in an extremely erratic manner in regard to their direction, rate and magnitude.

As a result of several years' concentrated observation of these variations under all possible conditions their chief characteristics are now fairly well defined and understood. Apart from their use in showing the limitations of direction-finding in its practical application, the results will be extremely useful in studying the problem of the propagation of electro-magnetic waves in both its theoretical and practical aspects. As giving some idea of the manner of these variations some of the observed results obtained with direction-finders taking apparent bearings upon fixed land transmitting stations are shown graphically in Figs. 11–13; and the following brief resumé of the general impressions gathered from such observations may be given.

While during the day periods the variations are limited to an extreme amplitude of approximately 7°, during the night both the frequency and amplitude of the variations are considerably increased. On some occasions the rate of variation is moderately great, amounting to several degrees per minute, while at other times the variation is in the form of a slow drift of the apparent bearing. The mean of large numbers of readings taken at night is very closely the same as the mean of similar readings taken during the day periods, this resulting in an approximately equal distribution of the variations on either side of the true bearing (*i.e.*, assuming no permanent local error exists).

This point is somewhat difficult to establish definitely, as the change in wave-length usually takes a few minutes to carry out,

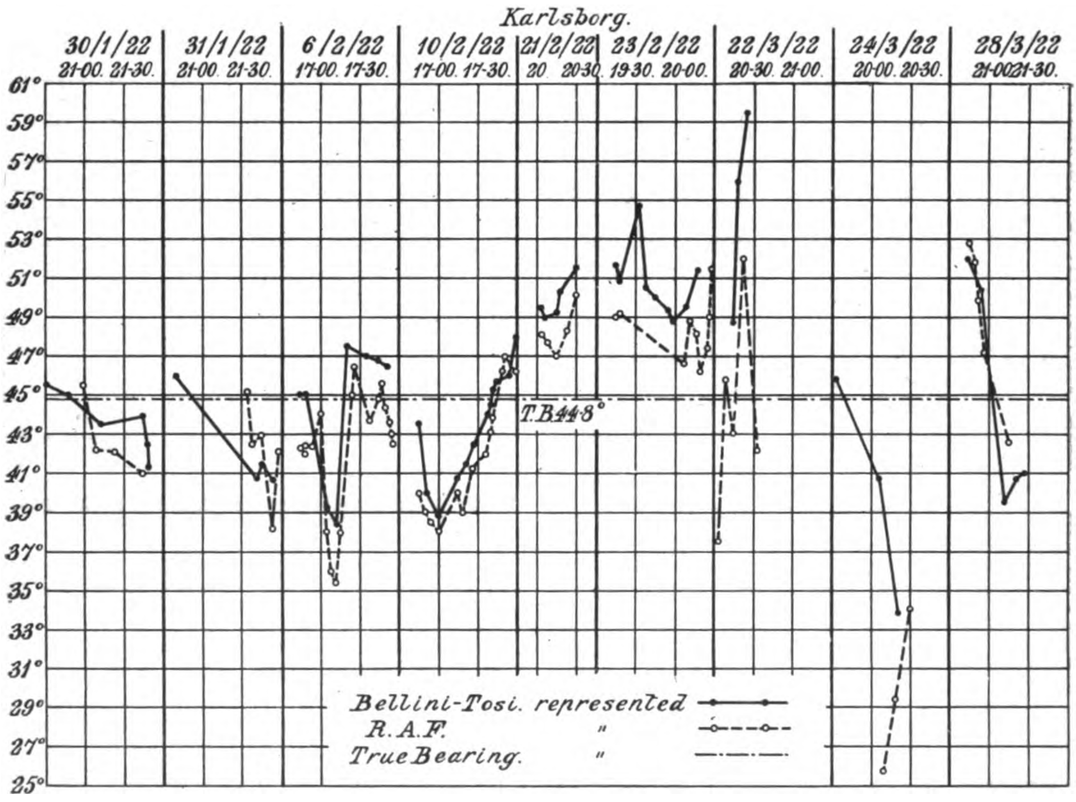


Fig. 11—Observations of bearings made at Slorgh, weeks ending 4th, 11th and 25th February, 25th March and 1st April.

and in this time the bearing may vary considerably even on the same wave-length. In the case of one transmitting station, however, it was consistently noticed that when the wave-length in use was changed from 4·2 to 2·5 km. the apparent bearing also changed by a much greater amount than would have been expected from the variations occurring either immediately before or immediately after the change in wave-length. In the case of double-wave transmissions, as from Leafield, it is frequently to be observed that the readings on the marking and spacing waves are drifting in opposite directions, and are often on opposite sides of the true bearings (Fig. 12). Since the mean bearings on either wave are practically identical the variations are again approximately equally distributed about the true bearings.

Fig. 13 shows some observations taken on the marking wave of Leafield on board a ship located at 40–50 miles from the nearest land, which was practically in the direction of the transmitting station. This indicates that for waves emanating from an inland transmitter the variations are in no way decreased by propagation over the sea for the above distance before arriving at the receiver. Similar observations made at a coast direction-finding station show that, where the waves arrive over a direct sea path of over 400 miles there is no apparent decrease in the frequency and amplitude of the variations. When both the transmitter and receiver are situated on the coast, and there is a direct sea path between them, the variations experienced are usually negligible for distances up to the order of 80–90 miles, but at greater distances the same phenomena are experienced, as in the case of transmission entirely or partially overland.

These must be taken as some of the general conclusions arrived at from the observations so far made. They are in many cases somewhat difficult to confirm, as it is not practicable always to obtain the transmitter and receiver in the positions required, and also to satisfy all the conditions as to length of land and sea path in all directions around the receiver. For the tests of the different conditions involved it is necessary to employ several direction-finders located at different places, and there is always a slight element of uncertainty in assuming identity of other factors for purposes of comparison.

(j) A Possible Explanation of Variable Errors.

The theory which is usually put forward to explain these somewhat abnormal variations in observed bearings at night is an extension of that adopted to account for the great increase in range and the increase and variability in the strength of signals commonly experienced in night working as compared with day conditions. On this theory, which was elaborated by Eccles in 1912, the effect of sunlight operates on the propagation of the waves by reason of the ionisation of the earth's atmosphere In daylight the atmosphere is ionised practically down to the earth's surface, and the only waves arriving at the receiving station are those which are propagated directly along the surface of the earth. The increased resistance of dry earth as compared with sea water accounts for the more rapid attenuation, and hence the decreased range of transmission overland as compared with over sea. When, however, darkness sets in re-combination of the ions takes place in the lower regions of the atmosphere, and only at the top and rarer portions is there assumed to be a permanently ionised layer due to the influx of either electrons or dust particles projected from outside. Hence, for increasing altitude in the earth's atmosphere at night there is encountered a large increase in the ionisation gradient, and this supplies a comparatively well-defined surface which may act as a reflector of the long waves employed in radio communication. We thus see the possibility of waves arriving at the receiver at night after reflection from the upper layers of the atmosphere, which will add their effects to those of the direct waves in producing an increase in received signal strength. Also due to the fact that these waves travel through a clear un-ionised atmosphere they will suffer much less attenuation than the direct waves travelling along the earth's surface, and will thus produce detectable signals at night at places beyond the effective range of the direct waves in the daytime.

The theory of which the above is an extremely brief outline was extended by Eckersley and by Bellini to provide an

explanation of night errors in D.F. bearings. Due to the conductivity of the earth the magnetic field of the direct wave is assumed to be horizontal, since any vertical component would be quickly absorbed by the eddy currents in the earth. Except for irregularities in the earth's surface and any other causes, as mentioned above, of real or apparent deviations of the wave, this magnetic field is also perpendicular to the line of propagation. This assumption is justified very largely by the fact that in the daytime bearings observed upon a vertical frame coil or system of such coils are reasonably accurate.

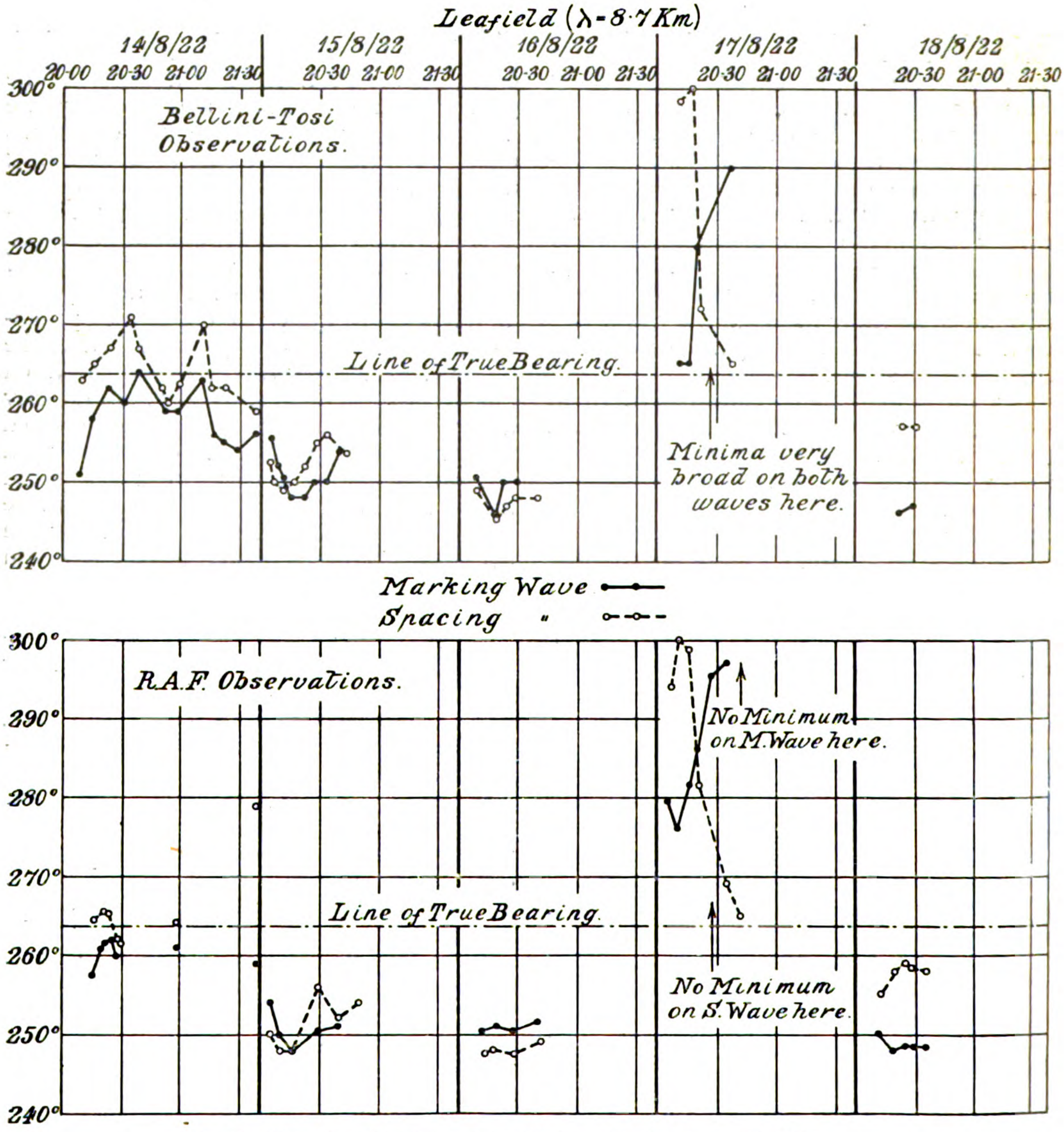


Fig. 12.—Observation of bearings made at Oxford, week ending August 19, 1922.

The wave which travels up into the atmosphere, however, need not be polarised with its magnetic field horizontal, since there will

be no absorption of the vertical component. When this wave is reflected also at the upper hypothetical ionised layer, a rotation of the plane of polarisation of the wave may take place, whether the previous polarisation was such that the magnetic field was horizontal or vertical. The possibility is thus seen of the reflected wave arriving at the receiver with its magnetic field in directions other than the horizontal. In the general case it will be inclined, and taking the projection of it on a horizontal plane which gives the on the direction-finder will be ill-defined and the direction will be given by the major axis, resulting in an error of bearing which may vary within wide limits. In the case of a circular resultant field no change in signal intensity will be experienced as the coil or loop is rotated, and no bearing at all can be determined. When the phases of the two waves differ by an integral number of half cycles a linear resultant will be obtained giving a sharp bearing, which may be considerably in error, depending on the

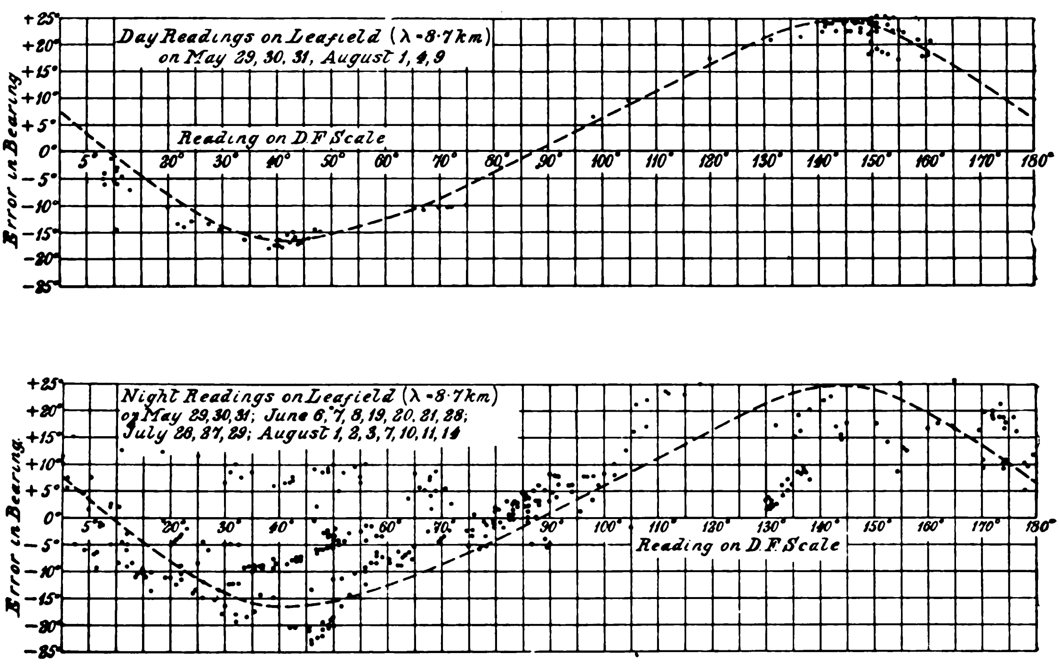


Fig. 13.—D.F. Observations made on a ship at about 50 miles from land.

only component which will affect a vertical coil, it will be appreciated that this horizontal component will not necessarily be perpendicular to the path of travel of the waves. The effect on the D.F. coil will be that due to the resultant of the horizontal components of the magnetic fields of both the direct and reflected waves. Now, since the reflected wave has arrived by a longer path than the direct wave, the two may or may not be in phase at the receiver. The resultant horizontal magnetic field, therefore, will not necessarily be linear, but either elliptical or circular. In the former case the minimum relative magnitudes of the two components.

Qualitatively, therefore, it is seen that most of the phenomena encountered in connection with wireless bearings can be accounted for on the supposition of this Heaviside layer. Previously, observations on this matter have not been available in sufficient numbers to make various quantitative checks on the theory. With the results now being collated it is hoped that sufficient data will soon be available for this purpose, and criticism of the theory must consequently be postponed for the present.

The D.C. Voltage Raiser.

By MARCUS G. SCROGGIE, B.Sc.

Since the voltage raiser was first described certain modifications have been made, and details of these, together with the theory of operation, should be of very great value to many readers.

ONE of the advantages of alternating current which has led to its almost universal use for large power schemes is the ease and economy with which it may be transformed to any desired voltage. This property is utilised to a large extent in providing the anode current (H.T.) supply for valve transmitters, both large and small. It is used by the B.B.C. for their stations, and also by very many low-power experimental stations. It is true that a good deal of complication is introduced in the form of rectifiers, smoothers, etc., but it is usually more economical than the use of D.C., where an expensive motor-generator is required.

In *The Wireless World and Radio Review* for August 15, 1923, and *Radio News*, November, 1923, a new device was described which steps up D.C. from the voltage usually supplied by town mains to a value suitable for valve transmitters, and which is both efficient and cheap in first cost as compared with the machines usually used for this purpose.

A considerable number of experimenters have now adopted this method, and satisfactory reports have been received as to its

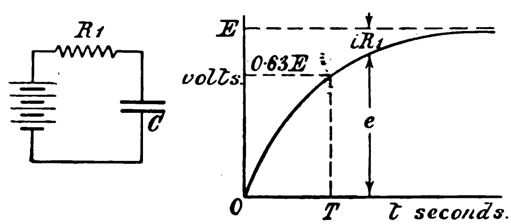


Fig. 1.—Illustrating the charging of a condenser through a resistance.

effectiveness. It is proposed now to give some further details with regard to it, but it is assumed that the reader is familiar with the original description referred to. It may, however, be mentioned briefly that the method consists in continually charging from the D.C. supply a number of condensers in series, the output being taken from the ends of the group of condensers. This process may be effected by a pair of brushes connected to the input and rotated by a small motor against a fixed radial commutator, certain sectors of which are connected to the condensers.

In order to design such a machine to fulfil certain conditions, it is necessary to have some knowledge of the theory underlying

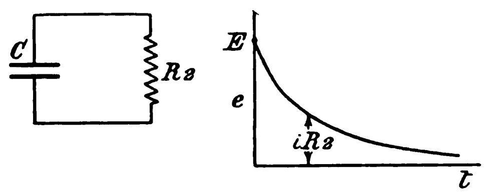


Fig. 2.—Showing the discharge of a condenser through a resistance.

it. For example, it is possible to design a much more economical machine for telegraphy than for telephony, and as many inquiries have been received on this point it will be as well to go into it more fully.

If a condenser is connected to a fixed supply voltage, current is forced into it until the back e.m.f. of the condenser due to this charge is equal to that of the supply. The difference at any given moment is that due to resistance, and where the resistance is small the time taken for a complete charge (theoretically a condenser never *quite* attains its complete charge !) is extremely small.

In Fig. 1 a battery of e.m.f. E volts charges a condenser of C farads in series with resistance R_1 ohms. The back e.m.f. of the condenser $e=\frac{Q}{C}$, where Q is the charge in coulombs (or ampère-seconds). The ordinates under the curve give e at any moment, while those between it and the ultimate value E give the drop in volts across the resistance$=iR_1$. The charging current i is therefore greatest at the moment of con-

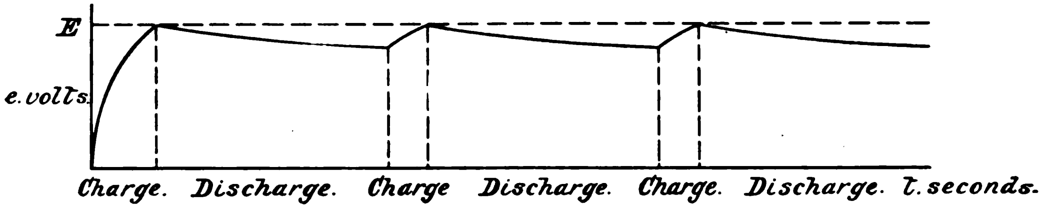


Fig. 3.—Curve showing voltage across any of the condensers.

nection and gradually falls off. The time taken for the condenser to receive 0·63···· of its final charge (the "time-constant" T) is R_1C seconds. To take practical values, if C is 1 μF and R 10 ohms, T is 0·00001 sec., and in 0·0001 sec. the condenser has received 0·999952 of its ultimate charge.

If the condenser is now removed and allowed to discharge through R_2 (Fig. 2), a similar but inverted curve tells the story.

In the voltage raiser each one of the group of condensers is periodically placed in contact with the supply for a short time, and throughout the whole time is discharging through the valve. If the condenser were very small and the load very big the former might be completely discharged before another charge was given, but in practice this is avoided. The voltage across any condenser is as indicated (Fig. 3).

The periods of charge for the other condensers in the series fall at intervals in between those for any one, so that the total e.m.f. across all the N condensers in series = NE volts, less a certain fluctuating amount due to the discharge. In order to simplify matters it may be assumed :—

(1) That each condenser is fully charged every time it is connected to the supply. How far this assumption is justified may be

(2) That the average output voltage is equal to the maximum less half the fluctuating voltage due to charging and discharging.

(3) That the output current is constant at the average output voltage. This is very nearly so provided the voltage fluctuation is small, as should be the case where a smooth carrier wave is desired.

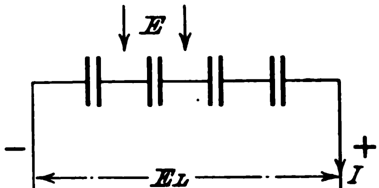


Fig. 4.—The voltage E is applied to each of the condensers.

The following symbols will be used throughout :—

E = supply voltage from mains.
E_0 = maximum (no load) output voltage = NE.
E_L = actual output voltage on load (average).
δE = amplitude of fluctuation on output voltage.
I = average output current (amperes) to valve.
W = average output power (watts) to valve = $E_L I$.
$W_{max.}$ = maximum output power (watts) obtainable from the machine.
N = number of condensers in series.

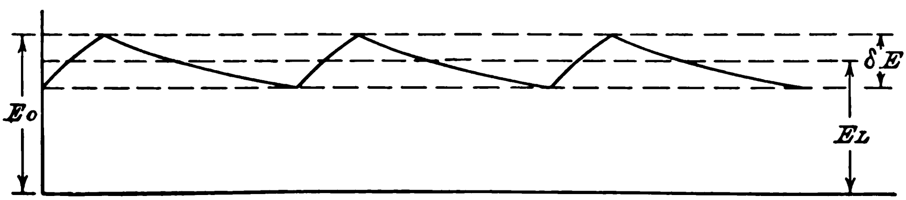


Fig. 5.—Diagramatic representation of the conditions obtaining when the voltage is applied to the condensers.

calculated as previously explained. Practically the only resistance in the charging circuit is an optional one of 10-20 ohms to limit the current in the event of a short circuit.

C = capacity of each condenser (farads). (Always remember to multiply by a million to give the more familiar microfarads (μF).)
n = number of times any condenser is charged per second = $\frac{RS}{60}$

R = revolutions per minute of brushes.
S = number of charges on any condenser per revolution.

Whenever the voltage across a condenser alters by an amount e, the quantity of electricity passing in or out (according as e increases or decreases) is $Q = Ce$.

In our case, with the foregoing assumptions—

$$Q = It = I \times \frac{1}{n}$$

$$\text{and } e = \frac{\delta E}{Cn}$$

$$\text{so } \delta E = \frac{NI}{Cn}$$

$$\text{Now } E_L = E_0 - \frac{\delta E}{2} = E_0 - \frac{NI}{2Cn} \text{ (Fig. 5)}$$

$$W = E_L I = E_0 I - \frac{NI^2}{2Cn}$$

$$= NI\left(E - \frac{I}{2Cn}\right)$$

It will be seen that if $\frac{I}{2Cn}$ is greater than E—in other words, if the condensers are completely discharged in less time than is allowed between charges—the equation ceases to have any practical meaning in this connection, so that it must be assumed that $\frac{I}{nC} \ngtr E$.

It is interesting to find the maximum power ($W_{max.}$) that can be obtained from a machine. It may be shown* that $W_{max.} = \frac{NE^2 nC}{2}$, and that $\delta E = E_0$, so that each condenser is just completely discharged before being re-charged, the output voltage being half the maximum.

If the maximum power is used, then, besides the voltage being low, the transmitted wave is a completely modulated tonic train unless smoothing circuits are used, and is useless for telephony, besides causing interference. It is advisable, therefore, to make the voltage fluctuation as small as possible. The percentage fluctuation is $\frac{\delta E}{E_0}$, and can be shown to be approximately $\frac{W}{NE^2 nC}$ *for small values.* For a given power and fixed supply voltage and charging speed this is inversely proportional to NC or the total capacity of condensers used. So that other things being equal, the larger the capacity the smoother the output, or, on the other hand, if the percentage fluctuation is kept the same, the output is proportional to the condenser capacity.

It will also be quite evident that it is an advantage to have n and E as large as possible, but the latter is not usually under control (or there would be no need for the machine at all), while mechanical considerations limit n to somewhere of the order of 100. If the machine charges each condenser twice per revolution and runs at 2,000 r.p.m., then $n = 67$.

In the original design brushes were moved round against a fixed radial commutator, but, of course, an obvious alternative method of construction is to have a fixed cylindrical commutator made from a copper tube, and mounted on an insulating tube of ebonite or other suitable material, being spaced from it by small condenser spacing washers, in order to prevent metallic dust between segments causing a flash-over due to the high voltage (Fig. 6). The copper tube is first screwed down with countersunk screws and then sawn across at various places as indicated. To avoid short-circuits between the brushes a dead segment is placed between each live one, while the two between the end terminals are each 50 per cent. larger than their fellows.

The diagram shows a four-stage raiser, but any number of stages may be used by arranging a suitable number of segments. Also by having double or three times the number each condenser may be charged twice or three times per revolution, leading to a smoother or larger output. Connections for a half-revolution three-stage machine are given in Fig. 7.

Carbon brushes are not suitable owing to the small gaps between segments causing

---

$$* \quad W = NI\left(E - \frac{I}{2Cn}\right)$$

$$\frac{dW}{dI} = NE - \frac{NI}{nC}$$

$$= N\left(E - \frac{I}{nC}\right)$$

$$\text{for max. } I = EnC$$

$$\text{but } \delta E = \frac{NI}{nC}$$

so $\delta E = NE = E_0$, *i.e.*, each condenser is just completely discharged, and

$$E_L = \frac{E_0}{2}$$

$$W_{max.} = E_L I$$

$$= \frac{NE^2 nC}{2}$$

them to wear rapidly, and the best type used so far is made of a number of phosphor-bronze laminations inclined at about 30 degs. to the surface.

These are carried on arms, with a piece of coiled spring wire pressing them on the commutator in the case of the cylindrical type, or the arms themselves may be springy in the radial type, the pressure being adjusted by screwing the plate on which the commutator is mounted back and forth along the axis of the motor shaft. The current is led to the brushes by rubbing contacts on two insulated parts of the rotating member. pair of contacts is connected to the supply and is vibrated by the cam, which raises and depresses the small insulating block between them. The fixed contacts are connected to the condensers in such a manner that connection is made from the mains to each condenser in turn, thus charging them. This method allows of much experiment as regards adjustment of duration of contact, phase angle, etc.

In order to make the procedure clear, two designs will be worked out, using the principles already given.

The first is for a 10-watt telephony

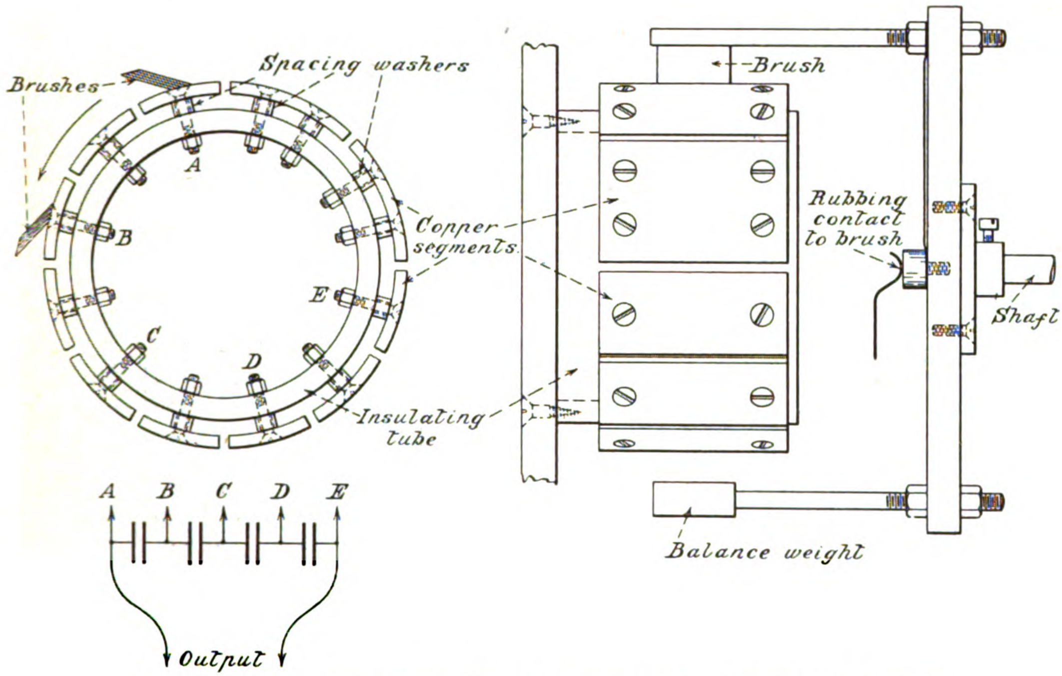


Fig. 6.—Illustrating the special construction of the commutator to prevent a flash over on high voltages.

To prevent vibration, a balance weight must be mounted on the rotating disc so as to oppose the force due to the brushes.

Yet another type of machine that has been proposed is worked by a cam carried on the motor shaft, which actuates a number of vibrating contactors. The general arrangement is as Fig. 8.

As many pairs of vibrating contacts are mounted round a fixed insulating piece as there are stages of raising (N), and corresponding fixed contacts are mounted on a piece fixed round the motor shaft. Each transmitter to operate from a 200-volt source, delivering at about 500 volts and the ripple not to exceed 6 per cent. of the maximum voltage.

Three stages of raising will be suitable, and the condensers may be charged twice per revolution, *i.e.*, N=3 and S=2. The brushes may be run at 3,000 r.p.m., either by direct coupling to a motor at that speed or by belt drive, in which case the motor may be slower, but must be more powerful as the belt loss would be a large part of the total resistance. A small fan motor is quite

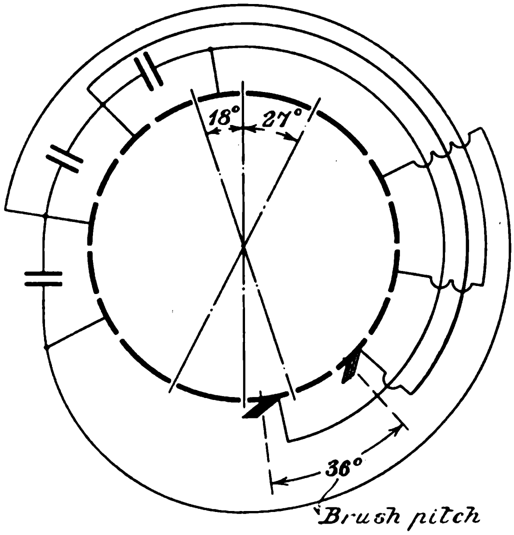


Fig. 7.—Connections for a half revolution, three-stage machine.

satisfactory, and may even require resistance to cut down the current to it, as the power required to work the brushes is extremely small, or a battery motor may be used run off the filament accumulator.

$$\text{We have } \frac{\delta E}{E_0} = \frac{W}{NE^2nC}$$

Filling in the appropriate values—

$$0{\cdot}06 = \frac{10}{3 \times 200^2 \times \frac{3{,}000 \times 2}{60} \times C}$$

$$\therefore\ C = 14\mu F$$

so that three condensers of this capacity are joined up in series.

E_L = approximately 580 volts
and I = 17 milliamps.

The maximum power obtainable from this machine is 84 watts at 300 volts.

The second example is for a tonic train transmitter, where the maximum power is made use of. Supply voltage, 250; output, 30 watts at 750 volts; brush speed, 2,000 r.p.m.

E_0 must be equal to $2E_L$, or 1,500 volts, so six stages must be used, and as this is fairly large only one charge per revolution will be arranged for.

I = 40 milliamps.

$$C = \frac{I}{En} = \frac{0{\cdot}04 \times 10^6}{1250 \times \frac{2{,}000}{60}} = 4{\cdot}8, \text{ say, } 5\mu F$$

so that six condensers of $5\mu F$ each are used.

An actual machine which is giving good results has four $18\mu F$ Mansbridge condensers, and works off 200 volts, giving 50 watts at 650 volts. The percentage fluctuation is 36 per cent., which is smoothed with chokes (Fig. 9).

A device may be mentioned for obtaining voltage variation and yet utilising all the condensers. The connections are as in Fig. 10.

A plug with three or more points fixed to an insulating holder is arranged to be pushed

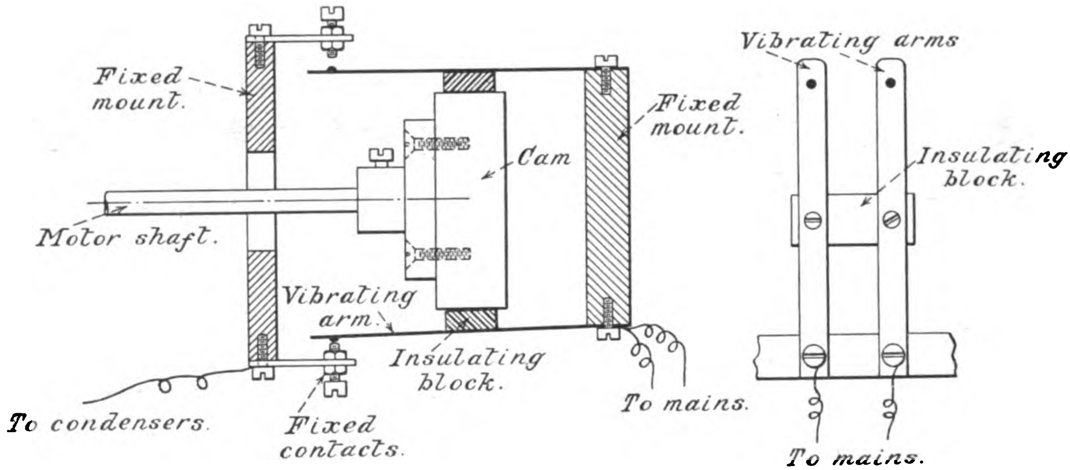


Fig. 8.—Illustrating another form of machine in which a cam operates a number of contactors.

into any three adjacent sockets as shown, and if the voltage across each condenser is, for example, 200, outputs of 400, 600 or 800 may be obtained by putting the plug into the appropriate sockets. The condensers are at the same time connected in the most advantageous manner. Instead of a plug a special switch can be used, and is more easy to manipulate but more difficult to make.

It might be asked if the principle could be adapted to A.C. working. Owing to the lack of A.C. supply the writer has not been able to test his theory in this respect; the following is offered as a suggestion to any who may have the facilities for trying such a device. The one machine takes the place of transformer, rectifier, and, to some extent, smoother. The chief difficulty that arises

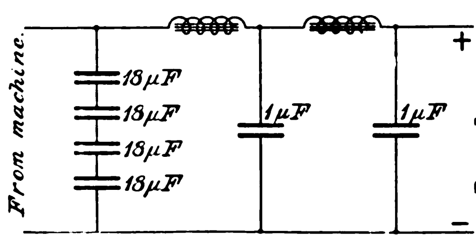


Fig. 9.—A suitable form of smoothing circuit.

is that a synchronous motor is necessary, and such is not to be obtained as readily as a D.C. motor. To those who like experimenting with A.C. the problem is an extremely interesting one to solve. A synchronous motor could be made from a small

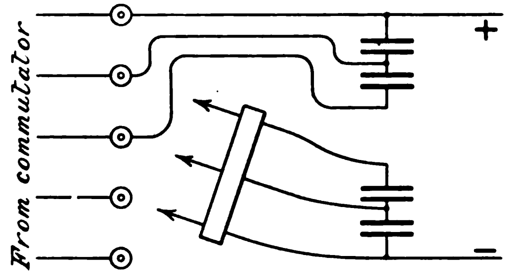


Fig. 10.—A system for obtaining voltage variation.

Assuming, then, that the brushes can be rotated at a fixed speed depending on the frequency of supply, the condensers can be charged in a similar manner to that already described, provided that the right moments are selected for contact.

Fig. 11 shows the sine wave voltage curve of the supply, which, for the sake of convenience, is assumed to be 200 volts 50 cycles. The maximum voltage is therefore 283, and if a condenser is in contact at the moment marked A it will be charged to that amount. The dotted curve indicates its gradual discharge after being disconnected at A, and at time B it is again at the same voltage as the supply, so this is the most opportune time for connecting it again as far as C; after which the process is repeated. It is assumed that the resistance in the charging circuit is negligible, and so the condenser voltage follows that of the supply exactly so long as it is in contact. If this were not so there would be a slight drop between the two, which might make it slightly more

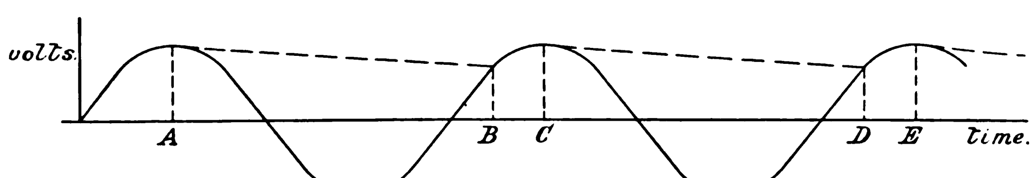


Fig. 11.—Line wave of supply voltage indicating the correct instant for contact.

induction motor by substituting rotating magnets for the squirrel-cage rotor, and using the stator winding on the supply mains in the usual way. Starting might be effected either by a short-circuited winding on the rotor causing it to start up itself and finally fall into step, or a small auxiliary battery motor.

advantageous to maintain contact a little past the maximum, as in Fig. 12.

Generally speaking, however, it would be near enough if the moment of maximum supply voltage coincided with that of the disconnection of the condenser.

The best moment for connection would depend on the extent to which the condenser

was discharged, as premature or retarded contact would lead to sparking and loss of power. A machine designed for small voltage fluctuation would require a very narrow "live" segment, while one worked near its maximum output would be better, with a wider contact. This factor is variable in the rotating contact type, but is fixed where a commutator is used. Another necessary adjustment is a device for rotating the contacts through a double-pole pitch of the motor, in order to arrive at the correct points C, E, etc., this being done whilst watching the output voltmeter to obtain the optimum point.

If the condensers were connected up in the usual manner, only one half of the wave could be utilised. To use both halves the connections are as in Fig. 13 for a four-stage set.

The motor must have as many poles as there are contacts—in this case eight—and with a 50-cycle supply will run at 750 r.p.m., charging each condenser twenty-five times per second.

The remaining particulars are calculated as for the D.C. machine, remembering, however, that the maximum voltage is 1·414 times the R.M.S. or rated voltage.

Readers of EXPERIMENTAL WIRELESS need hardly be warned that all due care should

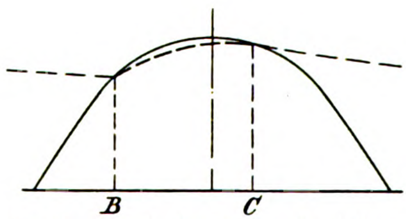


Fig. 12.—Curve showing duration of contact.

be taken in working with this class of machine, both as regards the power mains and the high voltage output, as a shock from the latter might easily prove fatal.

In particular the circuits should be well protected by fuses, and no part of the transmitter or its associated circuits should be directly earthed, as the output terminals of the machine are at a variable potential with respect to the mains, which are usually earthed somewhere. To guard against trouble a mica condenser should be placed in the earth or counterpoise lead, the capacity not above 0·01μF, as otherwise the H.T. supply will be reduced. In the writer's case, on one occasion when this condenser was not in use all six wires of the counterpoise were immediately fused across through falling on to a roof gutter.

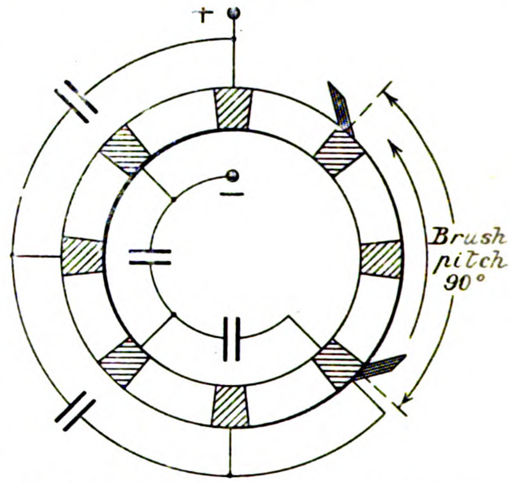


Fig. 13.—Showing the arrangement of the connections for a four-stage set.

The writer would be very interested to hear of any experimenter who has the facilities for investigating these machines with an oscillograph, as actual output curves would be very valuable and interesting in connection with the theory that has been given.

Transatlantic Messages.

On the night of January 16 2OD sent the following message to Hiram P. Maxim, of the A.R.R.L., via 1BQ, Canada :—

"Hiram Maxim, A.R.R.L., Hartford, Connecticut :

English Radio Transmitters Society send American Amateurs greeting stop Great pleasure that a number our Members have worked both ways with you on low power stop Hope next year we may assist you form round world amateur chain stop Happy New Year. IAN FRASER, Chairman, Radio Transmitters Society."

On the night of January 20 2KF received the following reply from Mr. Maxim (1XW) :

"Chairman Radio Transmitters Society: Your message received and very much appreciated by all at A.R.R.L. Headquarters. Hope I may soon see you in London in March. HIRAM PERCY MAXIM, President."

A New System of Radio-Transmission.

We summarise below a system of transmission which has been developed in America, and while it is not yet possible to give an opinion as to its value, it certainly provides much scope for amateur experimental work.

THE defects of present-day radio-transmission are many, and radio engineers have been experimenting for years in an attempt to improve existing methods. At present it is impossible to have more than a limited number of stations working on any particular band of wave-lengths, and when two stations "clash" the transmissions of both are usually spoilt as regards reception, particularly in the case of radio-telephony. Also static disturbances render communications unreliable quite frequently. Again, there is no secrecy in the normal method of transmission. These defects are all serious, and many different schemes have been propounded to surmount one or more of them. A new method will be described here of getting rid of all these troubles, which is due to the work of Mr. H. J. Tyzzer, of U.S.A.

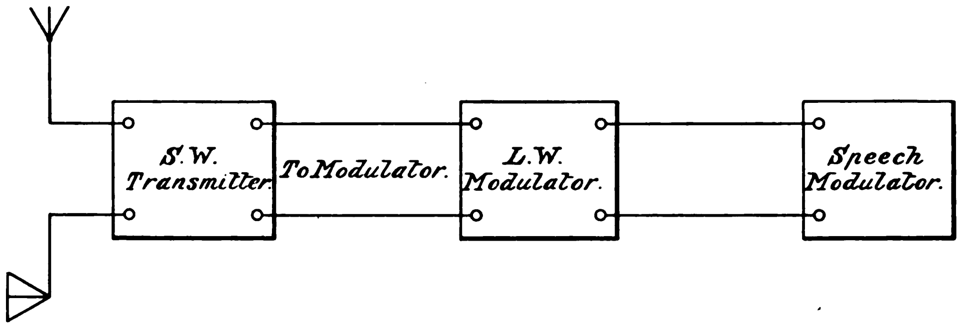


Fig. 1.—A diagramatic representation of the transmission system.

Many radio engineers have suggested various methods of "note tuning," *i.e.*, obtaining a beat-note of definite frequency and passing the resultant through filters, and, in fact, such systems are very widely used, but, unfortunately, this is not always entirely effective.

Similarly, interrupted C.W. has been used, and the note of interruption passed through filters, etc., but this is no better, if as good, as the previous system. In this new system interrupted continuous waves are used, but instead of interrupting the wave at an audible frequency a radio-

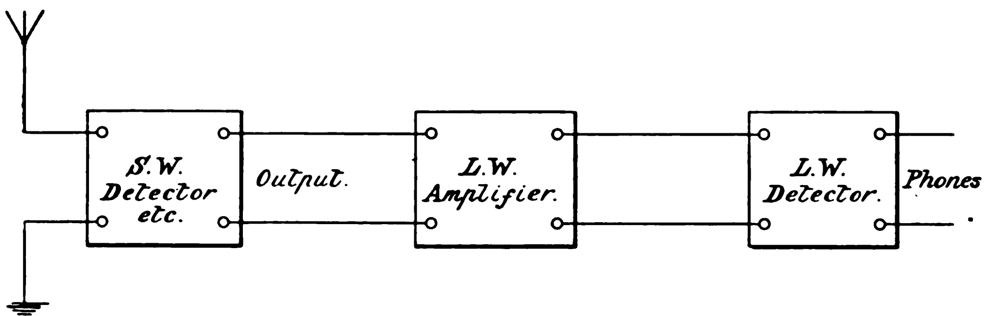


Fig. 2.—Illustrating the arrangement of the special type of receiver.

frequency is used. For example, if the normal transmission takes place on 200 metres this might be interrupted at a frequency of 100,000, corresponding to a wave-length of 3,000 metres. (These figures merely suggest a basis on which to work.) At the receiving end the 200-metre signal is received in the usual way, except that instead of the telephones a circuit tuned to 3,000 metres is used. Then several stages of R.F. amplification, and, finally, a detector, are used. The receiver is thus similar to the supersonic heterodyne without its separate heterodyne, though the system does not work on the same idea at all. It will be seen that it is only possible to receive signals when the receiver's first valve is tuned to the carrier frequency and the plate circuit to the modulation frequency. On an ordinary receiver only the pure unmodulated carrier is heard. We have here the possibility of getting a far greater number of stations in the wave-band at our disposal, as a large number of stations can operate near the same wave-length provided their modulation frequencies are sufficiently separated.

Also static disturbances do not influence the receiver at all greatly because the incoming disturbance will set up a train of oscillations in the first valve circuit at the frequency of the carrier, which will not appreciably affect the modulation frequency amplifier, as it is tuned to such a widely different wave-length. Obviously the modulation frequency amplifier must be carefully shielded to avoid picking up static and other disturbances directly on its own wave-length.

Further, telephony can be used by this system. The modulation frequency can, in its turn, be modulated at speech frequency, and so we can carry on telephone conversations by this method with great freedom

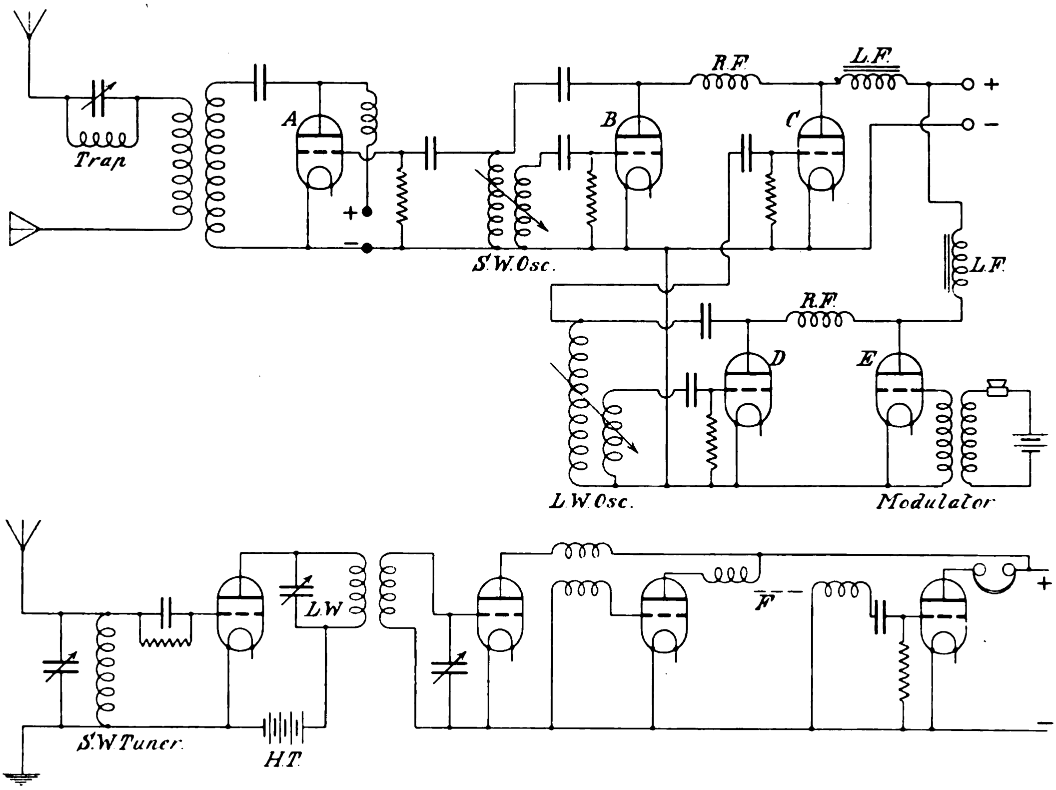


Fig. 3.—Above, is shown a complete arrangement for telephony control of the modulator frequency, while a suitable receiver is shown below.

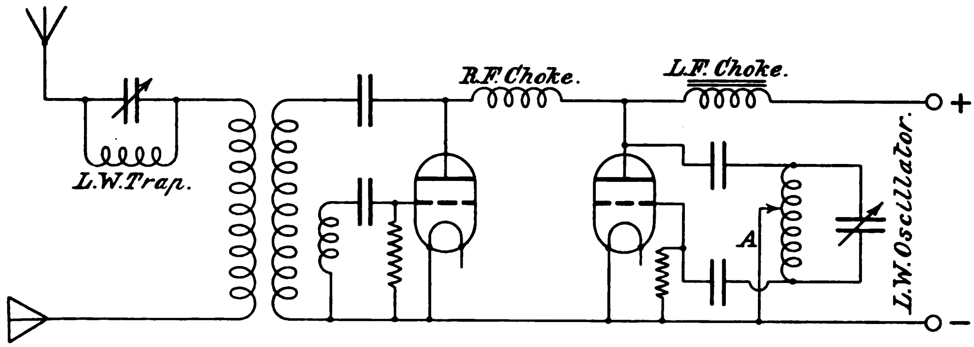


Fig. 4.—A simplified form of transmitter. The tuned trap prevents radiation of the modulator frequency.

from interruption. There are here incidentally possibilities of secret duplex working, which is much sought after.

It will be noticed that the modulation frequency must be of lower frequency than that of the oscillator. It is desirable that the frequencies should be well separated, and so it will be seen that the possibilities of this system are greater on short waves. The modulation frequency must not greatly exceed 20,000 cycles, and if telephone work is intended the speech quality will suffer if a lower frequency than about 30–40,000 cycles is used. A practical transmitter for C.W. is shown in the diagram, as is also a telephony set. A tuned trap should be used in the aerial circuit tuned to the modulation frequency, to prevent the radiation of that wave, or, alternatively, a loose-coupler should be used, or both on high powers. The diagram also shows a suitable receiving system. As many R.F. stages as desired may be used after the first short-wave detector, according to what is required. This system presents endless possibilities, and works as well in practice as it sounds in theory, so it is to be hoped that amateurs will experiment in this direction.

The Horticultural Hall Demonstration.

PERHAPS one of the most difficult tasks which the wireless enthusiast, whether amateur or professional, is called upon to perform is that of giving a successful public demonstration of broadcasting. By the use of suitable circuits it is possible to obtain practically distortionless amplification, and consequently it appears that the problem should be comparatively simple. This, however, is certainly not the case, and the difficulty lies in the acoustical rather than the electrical side of the problem. The amount of probable distortion, when using ordinary loud speakers, increases very rapidly with the volume of sound required, and as soon as any attempt is made to cover a large area it is almost essential to adopt entirely different methods. The demonstration at the Royal Horticultural Hall on the occasion of *The Model Engineer* Exhibition proved to be no exception to the rule ; in fact, the acoustical and electrical conditions of the environment were far from what was expected, with the result that the special apparatus which had been built for the demonstration was substituted at the eleventh hour by other equipment.

The initial experiments were made in the EXPERIMENTAL WIRELESS laboratory, where it was hoped to duplicate the conditions likely to obtain in the Westminster district. The laboratory is situated about ¾ mile from 2LO. An inside aerial, about 15 ft. long and 2 ft. below a lead roof which covers the

laboratory, was used for testing the tuning and rectifier apparatus. The measured rectified current from 2LO was found to be of the order of 60 microamps. The amplifier was built in the laboratory and tested some 15 miles out of London, a crystal rectifier and an ordinary outside aerial being used. The rectified current from this was approximately equal to that obtained in London. The amplifier and loud speaker gear were tested in the open between two houses, so as to imitate more nearly the conditions likely to be found in the Hall. After some little experiment with a four-valve resistance-coupled note magnifier in conjunction with Amplion loud speakers, excellent quality speech and music were obtained at a distance of about 30 yards from the loud speakers. The apparatus was then transferred to the Horticultural Hall on the evening prior to the Exhibition. An attempt was then made to determine the most suitable aerial, and a wire about 50 ft. long and 15 ft. high was tried was a 100-ft. wire attached to the top of the glass roof of the hall. This, it may be mentioned, necessitated a hazardous climb over a multiplicity of iron ladders and duck boards, at all angles between the horizontal and the vertical, which terminated in a kind of hatchway. Through this we crawled, together with a collection of aerial wire, insulators, wire cutters, etc., and found ourselves on a little trolley some 80 ft. up in the ether. The trolley had to be moved to the centre of the roof. This was accomplished by turning a crank connected to a sprocket, which transmitted our muscular energy to the driving wheels *via* what seemed to be a very slender bicycle chain. We were much too interested in the probable efficiency of the new aerial to consider how one reaches *terra firma* when the chain breaks. Having made fast the aerial to a neighbouring girder, and left the free end in the care of an assistant below, who meanwhile entangled it amongst

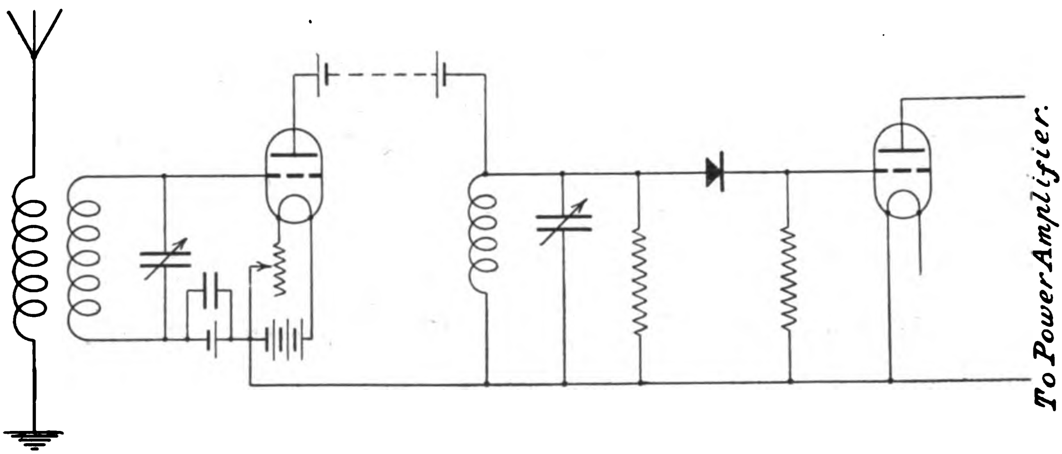


Fig. 1.—Showing the tuning, radio frequency amplifier and rectifier circuits. Note the various control devices.

stretched diagonally across the lounge. To our surprise the received energy from 2LO, about one mile away, was a negligible quantity. We were quite aware of the fact that the building was a steel structure, and, although considerable screening was expected, the results obtained were not in accordance with our previous experience under very similar conditions. As it was desired to limit the amplification as much as possible, the obvious procedure was to improve the aerial. The next system to be all the available power lines, telephone lines and exhibitors' stands, we cranked our way back to the hatchway and repeated, in reverse order, our simian antics of half an hour before.

The new aerial was worse than the first. True, the amount of energy which it passed on to the rectifier was infinitely larger than from the first aerial, but as this energy was derived chiefly from the aforementioned power lines it seemed to be of little value for our purpose. However, the result was

interesting, and we felt that our labours had not been in vain. The only alternative now remaining was an outside aerial. This proved to be impossible in the strict sense of the word, and the arrangement finally adopted consisted of an interior vertical down lead and an interior horizontal span disappearing through the top of an open window, continuing at some unknown angle to the top of an inclined flag pole on the entrance porch. All this, it may be mentioned, was on the far side of the building with respect to 2LO. The received current was now just measurable.

All hope of obviating the use of radio-frequency amplification had now been abandoned, and accordingly the original tuner and rectifier were hurried back to the workshop for the inclusion of one stage of H.F. amplification. While these alterations were being carried out the Exhibition opened and gave us an opportunity of examining the true electrical and acoustical conditions of the Hall. The result of the investigation showed that the following were in operation throughout the day :—

Straight wiring on power lines.
Straight wiring on light lines.
Electric motor (one yard from receiver).
Electric flashing signs.
Wimshurst machines.
Spark coils.
Ultra-violet ray device.

However, by the use of three tuned circuits the above were reduced to little more than a threshold effect, even on full power. The converted tuner had now arrived, and the rectified current from 2LO was found to be of the order of 40 microamps., which it was hoped would be of sufficient magnitude to operate the resistance amplifier. The resistance amplifier, it may be mentioned, was designed to operate at a moderate efficiency with a fairly high input. On connection the amplifier was now found to be inoperative after the second stage. Why it should have broken down is difficult to suggest, and it now only remained to return it to the laboratory and search for the broken-down condenser, resistance or leak. By this time both the authorities and the public were making anxious inquiries as to the existence of the Broadcasting Demonstration. It was no good offering technical explanations; we could do little else than crave their patience. While another amplifier was being procured it was found that the coupling between the aerial and closed circuits had to be so reduced to eliminate interference, that the rectified current was considerably diminished, thereby lowering the output to the resistance amplifier to such a degree as to make it of little value. This pointed to the use of an amplifier of much greater efficiency and a two-stage transformer-coupled power amplifier, preceded by a direct-coupled note magnifier was employed, the standard Western Electric power amplifier meeting the requirements. This was operated in conjunction with two Western Electric loud speakers, which were very

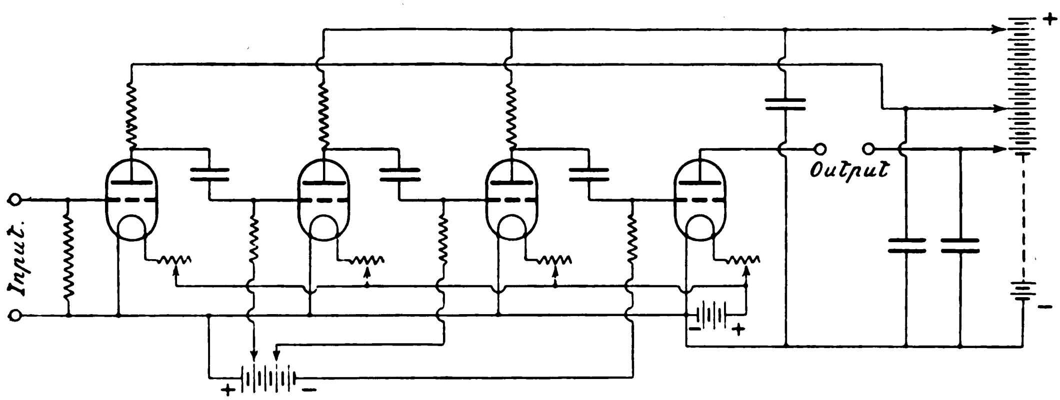


Fig. 2.—In the resistance coupled power amplifier all variable quantities were provided with separate control, as shown.

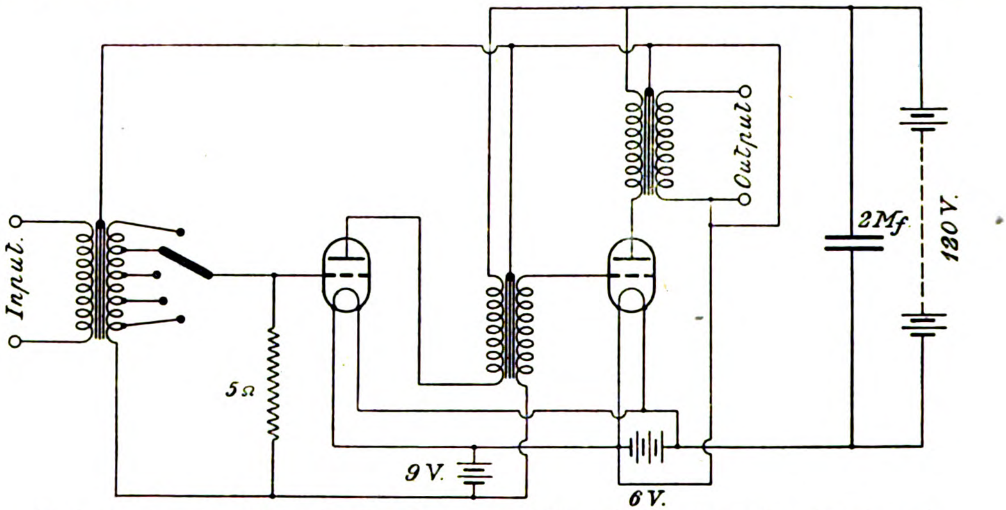


Fig. 3.—The arrangement of the amplifier shown above ensures stability and quietness in operation. The valves used were Western 216a type.

kindly lent by the Western Electric Co., Ltd., to whom we offer our thanks.

When the amplifier was finally in working condition the amplified output was examined by a shunted telephone, and it was found that both speech and music were of excellent quality. Accordingly the loud speakers were connected to the output—with terrible results! The loud speakers were mounted on a bracket some 8 ft. high in the corner of the lounge. Apparently half the emitted sound impinged upon a very deep girder in the middle of the lounge and over almost the entire frequency range the resonance was considerable. This was overcome by lowering the loud speakers to a height of only some 4 ft. from the floor. Everything within the lounge now seemed very beautiful, but on walking into the body of the hall amongst the nearby stands the most appalling noise ever heard reached our ears. It appeared that the sound waves were following a multiplicity of paths among the numerous gangways, and on reaching the ear the direct and reflected waves were all out of phase. At the farther end of the hall this effect was not noticeable, due, perhaps, to the fact that the angles of incidence and reflection were more obtuse.

Perhaps a few details of the apparatus used will be of interest. Throughout the whole circuit every effort was made to eliminate distortion. Excessively sharp resonance in the high-frequency circuits should be avoided, and for this reason the aerial circuit consisted merely of an inductance; this arrangement, in conjunction with a fairly highly-damped aerial, was not very resonant. Both the capacity and inductance in the closed circuit were capable of adjustment, and the inductance was wound with fairly fine wire. A similar arrangement was used in the tuned anode circuit; in this case a 50,000-ohm resistance was shunted across it. Every precaution was taken to reduce retroactive effects to zero. Rectification was accomplished by a galena crystal, which operated on a fairly parabolic portion of its characteristic. The crystal was connected to the grid of the first amplifier, the potential being controlled by the input resistance. This was either resistance-coupled to the resistance power amplifier or to the input transformer of the other amplifier. The output from the amplifier was shunted by a variable non-inductive resistance. The transformer-amplifier calls for some comment. The ratio of the input transformer is variable, being tapped on the secondary and shunted by a half-megohm resistance. The transformer cores are electrically connected and earthed. The actual transformers are specially built for speech amplification, and give practically equal amplification at all speech frequencies. Unfortunately, we are not at liberty to disclose the special method of construction employed, although, no doubt, many readers are really familiar with the principles which are involved.

Valve Manufacture: Some German Methods.

By Dr. A. NEUBURGER.

While experimenters are familiar with receiving and transmitting valves of all types, probably little is known of the method of manufacture, and the following description of German methods should be of great interest.

As the manufacture of German valves was developed during the recent war, it was not influenced to any great extent by those methods employed in other countries, and, therefore, a great many distinctive features are to be found. The first apparatus for valve manufacture on a commercial scale was installed by the Telefunken Co., after a considerable amount of experimental work. Previous to this valves had only been manufactured in a very primitive manner and

Fig. 1.—Turning the glass feet on a "lathe."

only in very small quantities. In these early experimental valves it is interesting to note that the electrodes were hammered out from ten-pfennig pieces, which, of course, consisted essentially of nickel. The preliminary experiments proving successful, a large-size factory was erected, equipped with machinery of the latest type, including several machines for special work. Much time was then devoted to the development of methods suitable for mass production. The results obtained were very gratifying, as similar experiments on other forms of tubes, such as the Roentgen tube, had not been very successful in many directions.

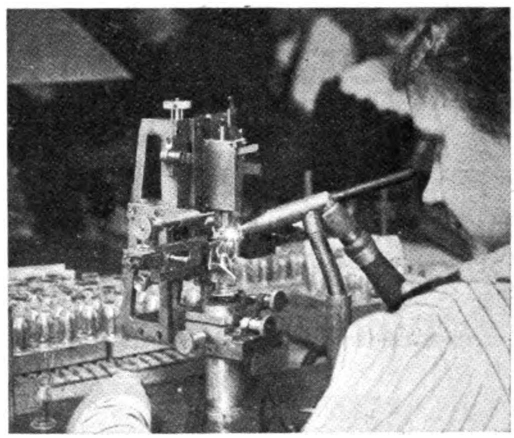


Fig. 2.—A machine which forms and welds the electrodes.

The machinery used for the mass production of the electrodes is of considerable

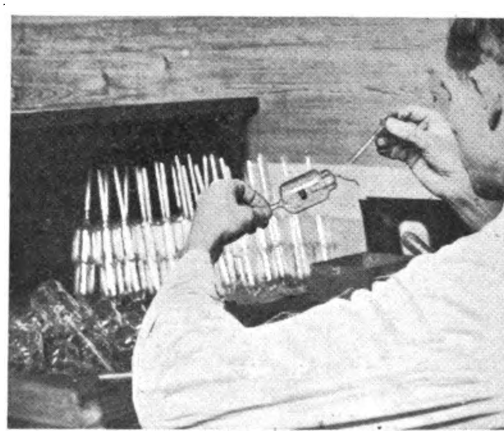


Fig. 3.—Welding the foot into the bulb.

interest. Essentially the machines are fitted with a number of levers and other arrange-

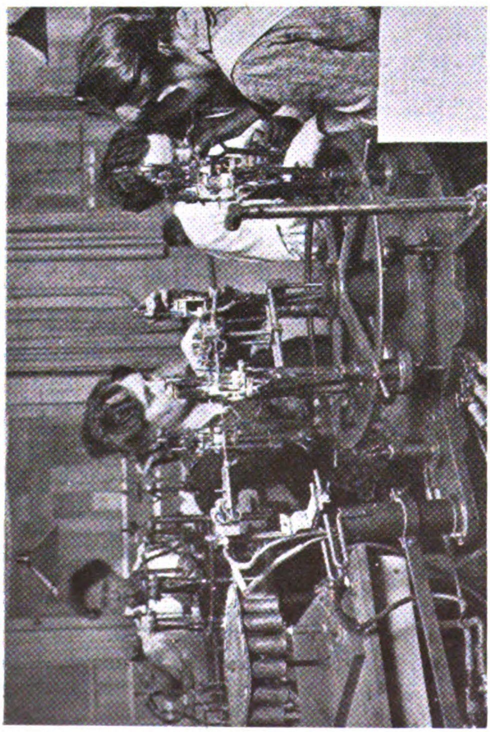


Fig. 4.—A near view of the foot pressing machine.

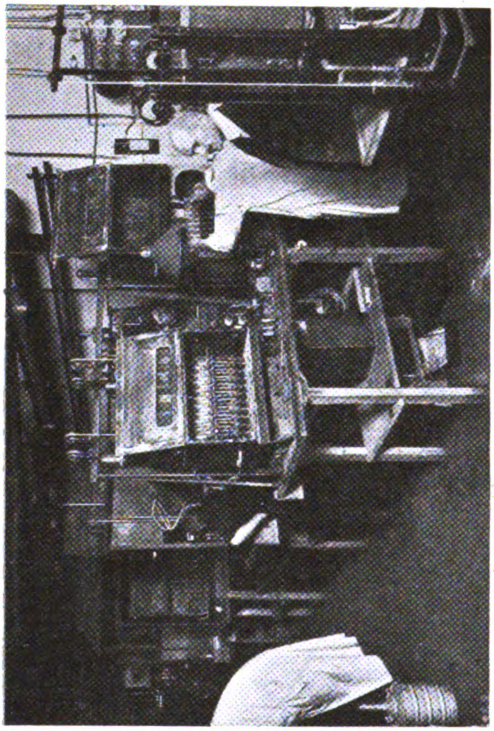


Fig. 5.—An evacuation room in which 2,000 valves are pumped daily.

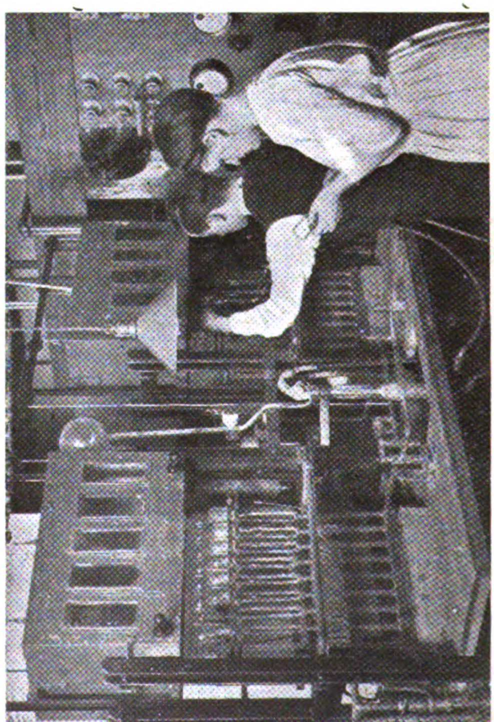


Fig. 6.—Valves connected to glass "forks," prior to entering the furnace.

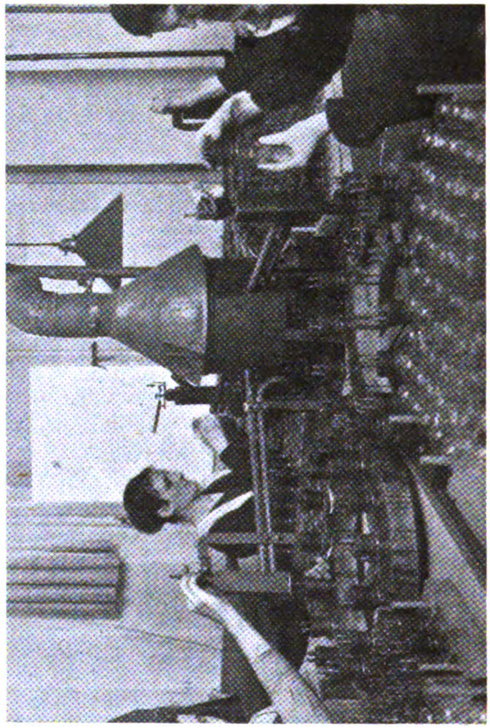


Fig. 7.—The machine used for fixing the caps to the valves.

ments, which are operated in a pre-determined order, so that when each electrode has been bent into shape by the machines, they mechanically come into the correct position in respect to each other. As the method of the leads and the electrode supports are prepared in an automatic machine, which adjusts their length accurately. Before they are fixed into the stump they pass through a gauge, which determines their relative posi-

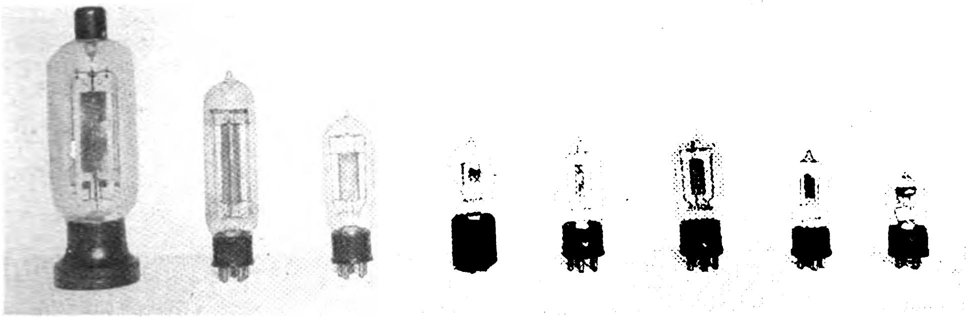


Fig. 8.—Some latest types of German receiving valves.

manufacture of transmission and receiving valves are in many ways identical, we will consider general manufacturing processes first, and deal with each individually subsequently.

The "glass feet" are made from glass tubing cut off in short lengths. One end of tions and depth of sealing. The stump is heated in two flames. The first flame gently warms it, while the second one gently softens it. The feet are then placed in an annealing installation which consists of a small cylindrical box containing asbestos heated by a gas flame. They are then passed to the

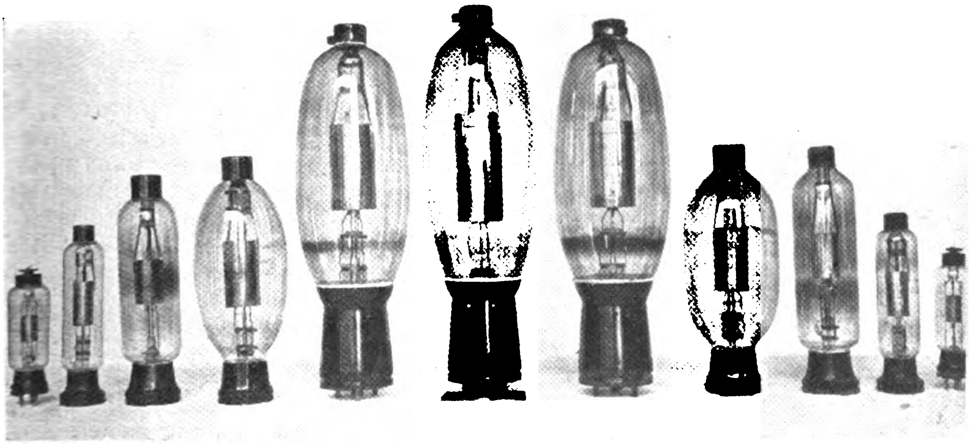


Fig. 9.—A collection of German transmitting valves. Note the peculiar shape of the bulbs.

each tube is softened in a flame and enlarged by turning in a machine which somewhat resembles a lathe. The leads and supports for the electrodes are then fixed to the feet and are then melted into the stump. Both presses, which are foot operated and are capable of dealing with some sixty feet in an hour. The presses work so successfully that only about one foot in a thousand will burst. The annealed foot first goes into the work-

shops, where the electrodes are mounted. First the electrode supports are shaped, and then the grid and anode and finally the filament are fixed. The electrode supports and the grid are both made in the same machine. The construction of the grid is

Fig. 10.—General view of testing room.

interesting. The blank grid is first stamped out from a thin sheet, and the stamping then goes into a second press, where it is stamped into the form of a grid-iron, finally being rolled and bent. For each of these operations a special machine is employed, which

Fig. 11.—Measuring the vacuum.

accurately determines dimensions and shape. As soon as the electrodes are made they have to be fixed to their supports, which is accomplished by spot welding. For this purpose electric welding machines are employed, and the actual welding is carried out in an atmosphere of hydrogen. The object of the hydrogen atmosphere is to prevent oxidation of the metal or alloys of which the electrodes are made. It is for this reason that the electrodes in a valve of German manufacture are always perfectly bright.

The attachment of the electrodes to the supports is semi-automatic, and the apparatus, which embodies various gauges, ensures an extraordinary high degree of equality. The first electrode to be fixed is the grid, after which the anode (which is stamped out in a similar machine to that used for the grid) is fixed, and finally the filament is attached to its supports.

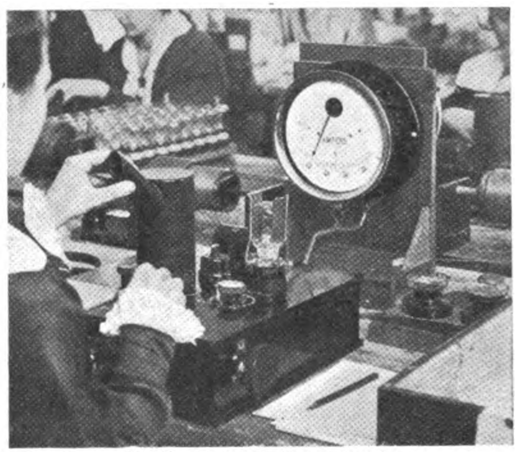


Fig. 12.—Measuring the amplification.

The glass bulbs in which the foot supporting the electrodes is to be fixed are made elsewhere, and are delivered to the valve factories in bulk. First of all a glass tube is melted on to the top of the bulb, which not only enables the bulbs to be handled easily, but allows air to be blown into them, which is necessary for subsequent processes. The bulbs are made somewhat longer than is required at the open end, and when this is adjusted to the correct length, the foot is brought into position and melted in. Then a second small tube is fixed to the bottom of the bulb, which serves for the subsequent evacuation process. After the second tube is melted on the first tube is removed and the opening closed in a flame. The small tubes fixed to the bottom of the bulb are then melted on to a series of other tubes, which

communicate with the vacuum pumps. The preliminary vacuum is obtained with ordinary mercury pumps, which are substituted by the familiar charcoal and liquid air device for final evacuation, during which process the bulbs and tubes are heated to the highest degree possible. During the process of evacuation the filament is, of course, heated and a high voltage placed on the electrodes in order to remove any occluded gases by bombardment. When the highest degree of evacuation is reached, as indicated by the vacuum meter, and further pumping shows that the vacuum is not increased, the small glass tube is closed by melting and effectively seals the bulb.

There are certain differences between the manufacture of reception and transmission valves. The anodes and grids of the transmission valves must have a greater efficiency than those in the ordinary receiving valves. For example, they must be capable of dissipating greater electrical energy, and there are only a few metals which, if heated even to red heat, are capable of maintaining a high vacuum. For transmission valves such metals as tantalum, tungsten, and molybdenum are employed, also certain alloys of various other metals are sometimes used. Care has to be taken when selecting suitable glass and Thuringia glass is universally employed. For transmitting valves the securing of the electrodes to the stump is always carried out with the aid of a foot-operated press. The filament is of tungsten, and is electrically connected to its supports by spot welding, and is kept in its correct position by a spiral spring. For the anode tantalum is used, which is stamped out from sheet, finally being rolled and made into the

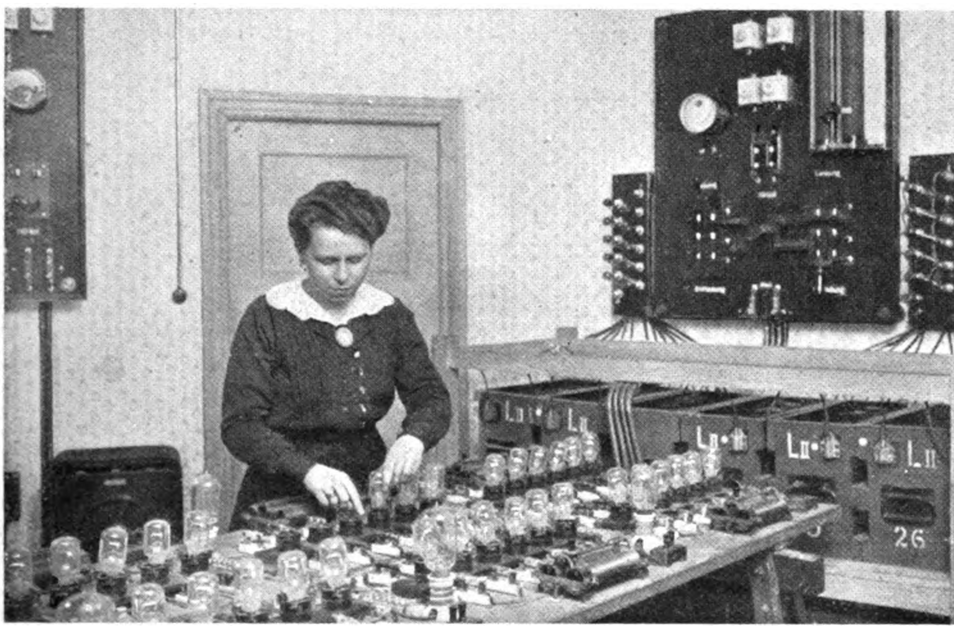


Fig. 12.—Ageing test of valves subjected to abnormal anode voltages.

form of a cylinder with the aid of electrical welding part. Before mounting the electrodes occluded gases are removed by placing them for several hours in electrically heated high vacuum furnaces, a very high temperature being maintained. When evacuating transmitting valves the preliminary vacuum is obtained by means of a diffusion pump, which gives a very high vacuum, the final vacuum being secured by the absorption method mentioned before. Great skill is required for the final evacuation process, as otherwise it is very easy entirely to ruin a valve. The completed valves go through various testing processes before being finally passed out of the fac-

tory. First of all, each valve is roughly examined by inspection. The filament is then tested in order to see that it has not been overheated during the evacuation process. This is determined by measuring the current necessary to make the filament begin to glow. The conductivity of each electrode is noted with the aid of a galvanometer. The degree of vacuum is measured by a special method described below. The procedure consists in measuring the ionisation which takes place with a definite voltage on the anode, the ionisation current being measured by the galvanometer. During this process, of course, the filament is kept glowing at a definite intensity. During these tests it is of the utmost importance to ensure that no oscillations are produced by the valve, and special arrangements are adopted with this end in view. Assuming that the vacuum has been found correct, the valve undergoes an ageing test with a super-normal anode voltage. If the valve passes the last test satisfactorily, it is stamped, marked, etc., and finally some of the tests just described are repeated once more in order to see that no change takes place in its characteristics. The valves are then considered as being suitable for wireless work and are then passed out from the factory.

Design for a Duo-regenerative Receiver.

By CAPT. ST. CLAIR-FINLAY, B.Sc.E. (Laus.).

In response to enquiries from experimenters wishing to set up the circuit described in the first issue of this journal in an article entitled, "The Design and Operation of Tuned Anode Receivers," a suggested layout for such a receiver employing three valve stages is here given.

IT will be noticed that the circuit has been somewhat simplified in certain respects, the L.T. connections to the first valve having been modified so as to give a neutral grid potential thereto suitable for all-round work with the majority of valves without necessity for special adjustments to provide this, and the final power stage originally shown having been omitted, since this will not usually be necessary, and can always be added if required as a separate unit, which many experimenters will already possess. The shunt leak between V1 and V2, the purpose of which is the maintenance of the grid circuit of the latter at a suitable normal potential, is now shown fixed instead of variable, as the value is not really critical, and will usually lie between 1 and 2 megohms, only the grid-leak proper being now variable; and the A.T.C. is now arranged permanently in series to enable short waves to be received, the A.T.I. being shunted by a vernier condenser of about ·0001 mfd. or less for fine-tuning, this being of some importance when a series-tuner is used, as it resonates the A.T.I. and considerably corrects the tendency to flatness of tuning which ordinarily characterises the series arrangement. Suitable tuning condensers of about ·001 mfd. capacity, in which a vernier adjustment, consisting of a small independent condenser of two or three plates arranged coaxially with the main set, is incorporated, are obtainable, and can easily be rearranged so that the main part is in series and the vernier in parallel with the A.T.I., and such an arrangement, which affords a neat and compact design, is shown in the present diagram, which also shows suitable switchgear enabling the L.F. stage to be cut in or out at will.

The switch is not arranged to control the filament simultaneously, as this is, in the case of the H.F. and detector stages, controlled by the rheostats only, switchgear being unnecessary, and it is thought better to standardise controls and make all alike as far as possible.

A circuit diagram and wiring diagram of the modified receiver are given in Figs. 1 and 2 respectively.

With regard to details—the panel should

not be made much smaller than shown in Fig. 2, as avoidance of cramping is essential if the full merits of the receiver are to be obtained. Components of really good quality should be used throughout, and will be found amply to repay any slight extra trouble or expenditure involved; and whereas this, of course, applies throughout a receiver, it is of special importance in the case of the intervalve transformer, poor quality of which may result both in loss of efficiency and in ruination of the quality of reception, and to the stopping condenser between V1 and V2, any leakage in which will cause more or less complete paralysation of the receiver through conveyance to the grid of V2 of high potentials from the H.T. battery. Good mica dielectric and not paper should be used here, and a transformer of reliable make for L.F. coupling, whilst a reliable type of variable grid-leak is also essential.

For the guidance of those who may not wish to make up their own components, it may be mentioned that the following proprietary makes have, amongst others, been found satisfactory by the writer, and may be used with confidence :—

Transformers.—R.I., Igranic, Sullivan, Lissen, Burndept and M.L.

Fixed Condensers.—Edison-Bell, Mullard, Dubilier and Burndept.

Variable Leaks (continuous).—Watmel and Lissen.

Variable condensers of the mica-dielectric type are compact, comparatively free from body-capacity effects, and, having a practically 360° movement, are less critical in adjustment than the usual air type and are very suitable for tuning purposes, particularly as regards the anode circuit. A rheostat with vernier adjustment is of advantage for control of the detector.

The wiring of the receiver should be carried out with clean copper wire of 18 or 20 S.W.G., preferably enamelled to prevent development of skin-resistance, particularly if the receiver is to be used in a large town, manufacturing district, or near the coast. For certain reasons, too involved to be entered into here, the writer is not in favour either of tinning of the wire or soldering of the connections, and whilst this latter may, of course, be done if desired, and will be reasonably satisfactory if carefully carried out, it is suggested and hoped that the bare statement will, for the present, be accepted that connections made with thoroughly cleaned wire and screw-terminals, well tightened up and finally shellacked at the joints, will be better electrically than the majority of soldered connections. The wiring should be carefully arranged, and that of the H.F. and detector circuits particularly kept as well spaced and isolated as possible.

No switchgear is provided on the H.F. side, as this is neither advocated nor neces-

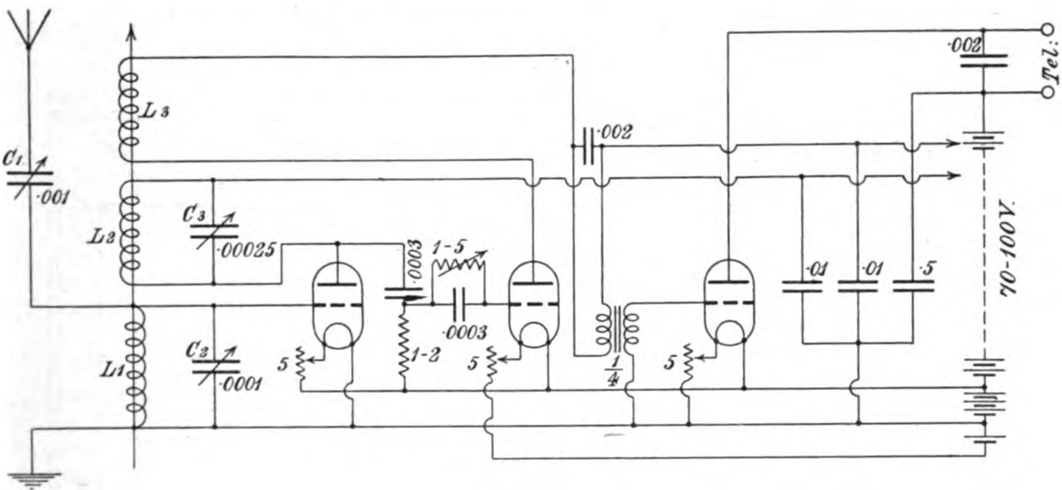


Fig. 1.—A modified form of the tuned anode circuit given by the author on page 41, October issue.

sary in the present case, since, when H.F. amplification is not required, V1 can be cut out of action and an ordinary regenerative closed-circuit receiver formed merely by turning out its filament—a feature of this circuit, further mention of which is made elsewhere in these pages.

A three-coil holder suitable for the usual plug-in coils is shown in the diagrams, and an instrument of the geared type is recommended as being really substantially made and affording a valuable degree of fine adjustment, although for short-wave work Gimbal-mounted coils would be somewhat better, and a holder suitable for this can easily be substituted if desired.

Direct 'phone connections are shown to permit of the addition of a power stage or the use of high or low-resistance instruments, as may be desired, in which latter case, of course, a suitable transformer would be connected externally.

It should here be mentioned that the value of the by-pass or telephone condenser shown in the diagram as ·002 mfd. should not be regarded as arbitrary. It should in no case be smaller than ·001 mfd., as this would interfere with its functions as R.F. by-pass and A.F. float, but it has the additional function of resonator to perform in regard to the transformer primary when the L.F. stage is in operation, and as this has an important bearing upon the resultant quality of reception and individual transformers, even of the same make and type, are apt to vary considerably in this respect,

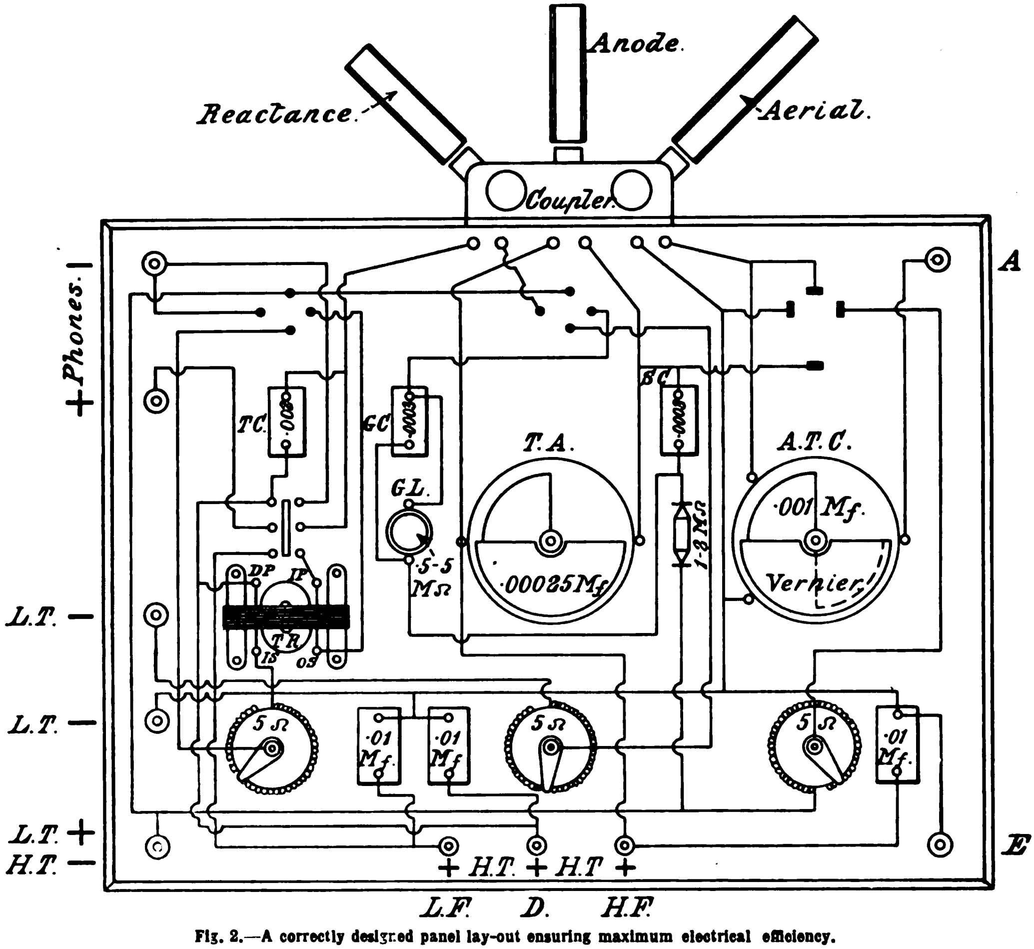


Fig. 2.—A correctly designed panel lay-out ensuring maximum electrical efficiency.

experiments with various values between ·001 and ·005 mfd. should be made until the particular transformer to be used has been suited. The same applies to the fixed shunt leak between V1 and V2, the best value for which should be determined by experiment with signals of medium strength before final installation.

Whether bright or dull-emitter valves are to be used, it is strongly recommended that a semi-soft detector of the Dutch type be used, as this will be found to suit the receiver particularly well and markedly to effect its efficiency, and to this end it will be noticed that a separate L.T. tapping is provided for the detector. These valves operate on about ·5 amp. at 3·5–4 volts, so that when dull-emitter valves are used at V1 and V3 the separate tapping, enabling an extra cell to be brought into the detector L.T. circuit, will usually be found necessary, though, of course, when bright-emitters are used throughout this will be unnecessary, and the two L.T. minus terminals should be shorted together by means of an external connecting strip, as shown in Fig. 2.

Should it be particularly desired to use dull-emitters throughout the B.T.H. B/4 valve will be found a very efficient detector, but here again the separate tapping will be called for, as this valve works on about ·25 amp. at 5–6 volts. Being hard, the plate voltage will not be found critical, but in the case of a semi-soft Dutch valve not more than about 50 volts H.T. should be applied, and should be kept well below the "blueing" point, which will usually be found to lie between about 60–80 volts.

With regard to operation of the receiver, tuning of the aerial circuit will differ somewhat from the more usual case where the main A.T.C. is arranged in shunt with the A.T.I., as in the present case C1 should be kept at as large a setting as possible consistent with correct tuning for reception of signals above about 300 metres, which means that the smallest possible size of coil, rather than the largest, should be used for the A.T.I. For short waves, on the other hand, almost the reverse applies, as in this case the largest possible size of coil should be used consistent with a reasonable setting of C1, which should not be allowed to fall to, or too closely approach, the zero mark. Initial tuning should in either case be done with the vernier C1 at a midway setting, use of the latter being finally made for fine tuning in either direction. The anode circuit should be tuned as usual, *i.e.*, the largest coil and smallest possible condenser setting being adopted in all cases unless a marked tendency to self-oscillation arises, in which case the policy may be reversed with advantage.

The couplings between the three coils L1, L2 and L3 should be so set that, with the two former tuned to resonance, and the most suitable size for the latter being used, V1 and V2 both just oscillate freely with full H.T. voltage and reasonably bright filaments, the H.T. and filament temperature being then reduced until oscillation ceases and stability of both circuits is obtained. Regeneration will then be adjustable at will simply by variation of the H.T. and filament temperatures, without disturbance of the couplings or tuning of the circuits.

If H.F. amplification is not required, it is merely necessary to turn V1 out, slightly tightening the coupling between L1 and L2, and re-tuning. if necessary, whilst V2 can, of course, be cut in or out equally readily by throwing over the switch controlling it and turning out its filament, one, two or three stages in any desired combination being thus instantly obtainable at will.

The receiver should be found very manageable, and no difficulty whatever should be experienced in its operation, whilst, if carefully constructed and handled, its efficiency should be about 50 per cent. greater than an equal number of stages ordinarily arranged, and quite as great as four stages (2H.F.) without reaction. Should any difficulties arise, however, they will gladly be cleared up, and experiences of amateurs with this receiver will in any case be learned with interest by the writer.

The Month's "DX."

Recorded by HUGH N. RYAN (5BV).

The increasing efficiency of amateur transmitters and receivers is resulting in the creation of many new long-distance records which are undoubtedly worthy of mention. It is proposed to record month by month work in this direction, and the Editor will be pleased to receive details for inclusion in these pages.

THE latter half of December and the first half of January is always the most interesting part of the year from the "DX" point of view, and this year has been no exception. At the beginning of December no British station had succeeded in sending signals across the Atlantic. We all hoped that the coming trans-Atlantic tests would result, at any rate, in a few of our best stations "getting over," and the more sanguine among us hoped that two-way working on fairly high power might be accomplished before the winter was over. But few even considered the possibility of two-way working before the tests commenced.

Events have moved very fast since the beginning of December, and it is now ancient history that 2KF established two-way working with 1MO on December 8, though the news only got into the tail end of these notes. This success was quickly followed by those of 2SH, 2OD and 5BV, all of whom established two-way communication across the Atlantic before the end of 1923.

The total numbers of American and Canadian stations worked by these four stations, and the approximate powers used, are as follows:—2KF, five Americans, one Canadian, 90 watts; 2SH, two Americans, one Canadian; 2OD, one American, one Canadian, 40 watts; 5BV, two Americans, two Canadians, 45 watts.

The most remarkable performances are those of 2KF and 2OD, the former because of the large number of stations worked, the latter because of the low power and also because 2OD has worked Canadian 1BQ so very often and consistently.

Since the end of 1923 we understand that a number of other British stations have established communication with America, but full details are not yet available. These stations include 2SZ, 2NM and 2FU.

That is a fairly complete account of the results obtained apart from the official trans-Atlantic tests. These tests extended from December 22, 1923, to January 10, 1924, and during that time the stations who had entered for the tests sent ten-minute schedule transmission every night, and each station had a different five-letter code word for each night. This code word he sent with the schedule transmission each night, and reception on the other side could thus be verified.

At midnight every night during the tests American 1XW (Hartford, Conn.) sent, on 100 metres, a report of the previous day's reception results in America and Canada. These transmissions were received in Europe by 8AB, PCII, 2KF, 5KO, 2KW, 5BV and others during the first part of the tests, but towards the latter part it is to be feared that most of these stations found that keeping up during the test periods of each night was quite a sufficient tax on the constitution, without listening for American reports as well!

At 12.45 each night R.S.G.B. station, 6XX, broadcast the results of the tests up to date. Up to the time of writing the following stations have been recognised by the R.S.G.B. as having been received, with code words verified, in America:—2FQ, 2KF, 2SZ, 5LC, 5PU, 6NI, 5BV, 2KW, 2NM and 2OD.

These are all ordinary amateur stations, and in addition to these 6XX, the special R.S.G.B. station, and 6YA, which, we understand, is being run by the members of a radio society, have been successful.

5KO does not yet appear in the R.S.G.B. lists, but 1XW has reported this station as having been received, with code word, and 1BQ gave me a message for him recently, giving his code word, which has been verified.

In addition to these British stations, six French stations (8AB, 8AE, 8BF, 8CT and 8LD) and three Dutch (PA9, PCII, oDV) have been received in the United States.

The tests have been very interesting from

several points of view. Firstly, they have shown very clearly the differences between the two classes of transmitting men. We have those who are keen experimenters, who design and make their own apparatus, and who operate it themselves. Also we have those who never perform any experimental work, who buy their sets ready made, who usually know no Morse whatever, and who are usually best known for the great number of gramophone records which they send.

Both classes of station took part in the tests (the latter employing operators), and success was, fortunately, almost entirely with the experimenters.

It was to be noticed, however, that while the stations of the former type transmitted only during their schedule periods, as was requested, and gave other people a clear field at other times, those of the latter type transmitted nearly the whole of every night, with a fine disregard for anybody else. But for this it is probable that more of the better type of stations would have been successful and none of the others.

Now that the tests are over we hear of an extraordinary trans-Atlantic success obtained by a station whom we usually associated with excellent short-distance telephony in and around London rather than with DX.

On the evening of December 27 2XZ was working on his usual 10-watt set, with another station only about 1½ miles away, and experimenting with pianoforte transmission. His transmission was received, on a nine-valve super-hetrodyne set, at Kansas City, Mo., 5,000 miles away. The speech and music are accurately reported, and there appears to be no doubt about the authenticity of the reception. There is no doubt that that night was an exceptionally fine one for long-distance work, and this result is in the nature of a "freak reception." But, nevertheless, it speaks highly of the transmission, and we congratulate 2XZ.

It was on this night that I first worked Canadian 1BQ, and his signals were of such great strength on one valve that, bearing in mind having been "had" on previous occasions by humorists with hetrodynes, I did not believe that he was a Canadian, much to his amusement, and that, I believe, of several British stations also! Later the same night 2OD worked him, and his signals were reported to be very strong, so it seems that it was a very fine night.

The best night since the tests so far was that of January 12—13, when some thirty Americans were heard in England on 100 metres alone.

By this time everybody knows that the 100-metre transmission of KDKA, mentioned in last month's notes, is a separate transmission and not a harmonic, as many thought at first. It is a very good transmission and will often work a loud speaker on two or three valves.

Some confusion was bound to arise in trans-Atlantic work owing to the fact that British and French call signs have their duplicates both in America and Canada. During the tests, of course, where only single-way work was involved, British stations prefixed their call signs with the letter G and French stations with F. This becomes very clumsy in two-way working, and the Americans have adopted the practice of using a distinguishing "break" sign instead of the usual "de." The sign is composed of the letter corresponding to the "called" station's country, followed by that corresponding to the "calling" station's country. The letters used are:—Britain, G; France, F; Holland, N; U.S.A., U; and Canada, C. Thus, American 2AGB calling Dutch PCII would call PCII nu 2AGB, and PCII would reply 2AGB un PCII. This is the most convenient way of avoiding confusion.

European "DX" is now in evidence again, though it was less interesting after the American work. However, much remains to be done in European work, chiefly in designing receivers which are selective enough to receive through the terrible QRM which we get nowadays, and sensitive enough to enable less power to be used by the transmitter, thereby lessening the QRM.

Nearly a year ago we used to read in French radio papers of a Swiss amateur transmitter, known as XY, but I do not think that he was ever heard in this country. He has apparently increased his power recently, as he is now quite strong. He first came in on January 6 at about 4 p.m., and at 5 p.m. 5DN called him, was heard, and worked him for some time. Another record for 5DN. This station seems to favour

Switzerland as the recipient of his record transmissions. He was using 10 watts, but his aerial current is now up to ·5, instead of the ·4 reported last month. No doubt he will reach the desirable ampère before long. May it travel in proportion to its size!

Mr. Neill, of Belfast, whose work I mentioned last month, has been doing well again this month, chiefly in reception of telephony from England. His best stations are 2ON and 2NM, both of whom he receives very well on telephony, the latter sometimes on one valve. He also receives speech from 2ZK, 2VF and 2IN, all of Liverpool district, the first of whom sometimes only uses 110 volts H.T.

In the West of England 5KO is going strong, having been heard in Algiers. 6RY is a fairly recent station, at Bath, but has already worked 8CT of Bordeaux.

I have just received from 7QF some particulars of amateur work in Denmark. He has sent me an enormous list of British, French, Dutch and Italian amateurs whom he has received. The very size of the list testifies to the excellent reception conditions in Denmark.

There are three active Danish transmitters at present:—7ZM, 200-220 metres, D.C. C.W.; 7EC, 190-210 metres, A.C. C.W.; 7QF, 180-210 metres, rectified A.C. All are near Copenhagen, and all have been heard in England on one valve. 7ZM and 7QF work on Saturday evenings, 7EC nearly every evening.

Yet another European country has entered the field of amateur transmitting work. Italy now has one transmitter—1MT, situated at Venice. He has already made a good start in "DX" work. 7QF has heard him often, and he has worked two British stations —2HF, near Birmingham, on December 9, and 5DN, of Sheffield, on January 13. 5DN was again using an aerial current of only ·5 amp. Some of the London stations must look to their laurels. They almost monopolised the success in trans-Atlantic work, but the North look like beating them in European "DX."

By the way, what extraordinary call signs we hear nowadays! PA9 sounded curious at first, but what about PAR14, who is often to be heard now? I believe he is somewhere in Holland. ACD is another mystery station, who often works 1MT (Venice).

TRANS-ATLANTIC TELEGRAPHY.

In view of the recent trans-Atlantic amateur transmissions it is thought that details of the apparatus used by some of the most successful participants will be of value to many experimenters.

British 2OD.

By E. J. SIMMONDS.

THE object of this article is to give the outline of a special transmitter, the construction of which was commenced late in November to participate in the recently closed trans-Atlantic tests. Owing to various delays, however, which will be discussed later, this set was not finished, and ready for test until December 21.

In view of this fact, and also because of the astounding success of 2KF in effecting two-way communication with U.S.A., it was decided to make an initial test with the same object, using the standard transmitter at the writer's station. From the diagram it will be seen that the circuit is one much used in U.S.A., being the well-known Hartley, employing as oscillator, Marconi AT.40X valve, H.T. from stepped-up A.C., 50 cycles, full wave rectification, and filament lighting from A.C. mains.

At 0315 G.M.T. Sunday, December 16, calls ARRL, etc., were transmitted for fifteen minutes with an input of 900 volts and 35 milli-amperes. At the termination of this

transmission, and on switching over to the receiver, a reply was immediately heard from American 2AGB, of Summit, New Jersey, who gave QSA. Two-way communication was at once established, and tests proceeded, until 0430 G.M.T., when 2AGB closed down.

The writer is bound to admit that his hand was distinctly shaky when recording the first reply from 2AGB, as it seemed so absurd and improbable, in view of the small power and valve in use.

It should be mentioned that through the kindness of Mr. Davis, of the G.E.C. Technical Department, Magnet House, Kingsway, a M.O. 250-watt valve was available, but the great difficulty was to obtain the necessary supply of H.T. to feed such a large valve, expense being, of course, a serious item. This difficulty was partially solved by the following method.

The H.T. for the small set is obtained from a step-up transformer, which has the usual centre tap on the secondary, and the approximate voltage between this tap and the outers, when on load, is 600 to 800 volts, depending, of course, on the main supply voltage, and the load on the secondary. It was, therefore, decided to use the two outers of the transformer, and rectify by a synchronous rectifier, and by this means double the H.T. voltage and also avoid the voltage losses so apparent when rectifying valves are used, and, of course, obtaining full wave rectification.

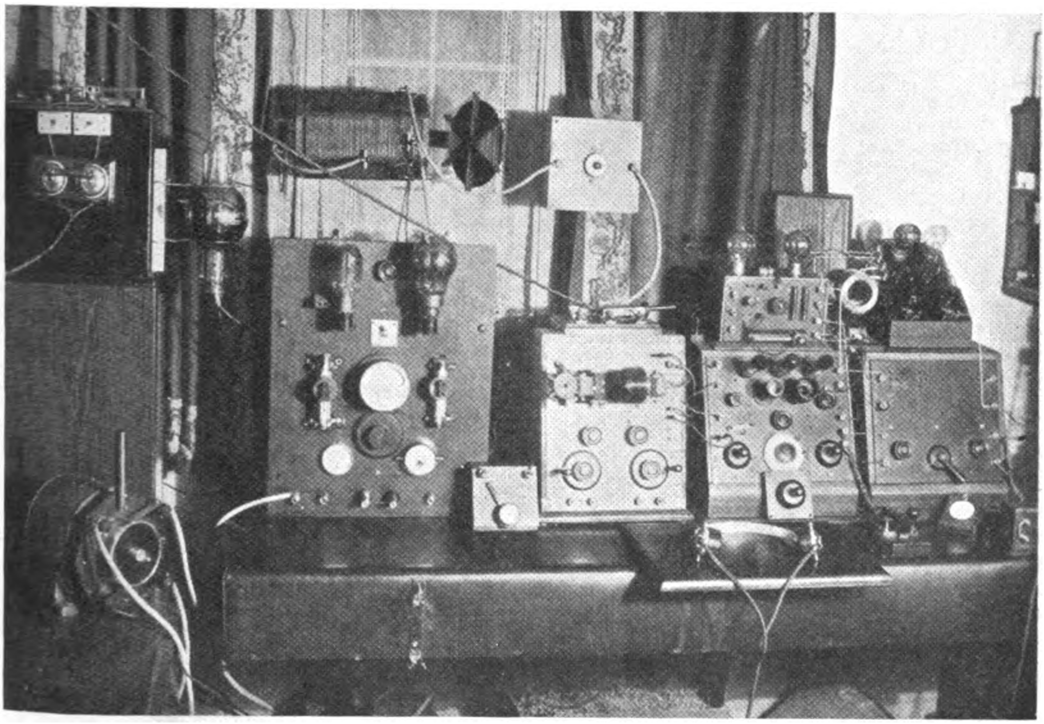


Fig. 1.—General view of set showing MO 250 and AT 40X valves, and also supersonic receiver.

Surely this is a world's record for two-way trans-Atlantic working, as at no time did 2AGB have any difficulty in reading signals from the British station, which were readable through QRN and QRM.

Confirmation has been duly received from 2AGB regarding the strength of signals.

Incidentally, the American reception must have been of high efficiency, and it is understood that a super heterodyne receiver was used. In view of this result it was decided to push forward the completion of the larger set with all speed.

In practice, however, it was found that with a load of 70 to 80 milli-amperes the

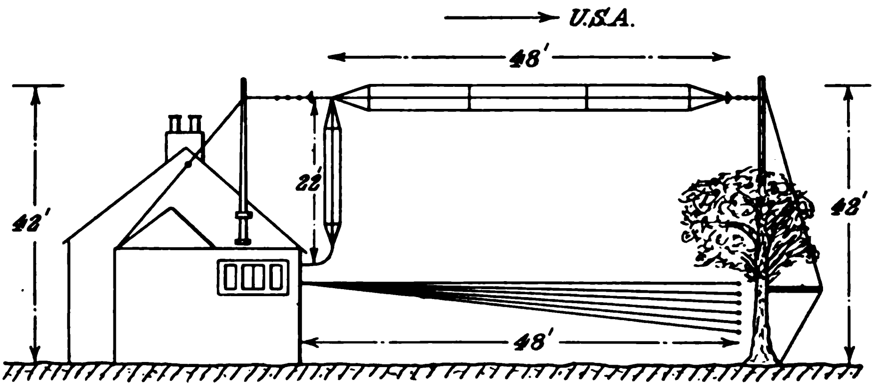


Fig. 2.—Arrangement of aerial and counterpoise systems.

voltage of the transformer secondary dropped to 1,200 to 1,300 volts.

This was, however, better than 600 volts, and the actual input to the 250-watt valve was 1,200 volts, at 75 milli-amperes, which, of course, is much under the rating of the valve.

Protecting fuses were inserted in the H.T. leads from the transformer to the rectifier disc, to obviate any chance of breakdown; as a matter of fact, in the initial tests, a short

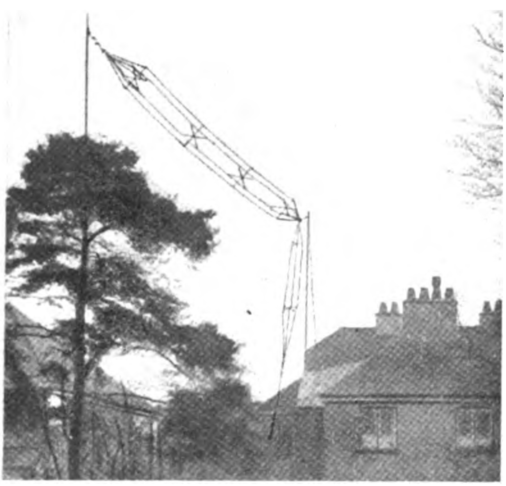


Fig. 3.—Aerial and surroundings at 2OD.

did take place in the transmitter, and these fuses undoubtedly saved the H.T. winding from being burnt out. The fuses were of platinum-silver wire, ·0015 diameter, and blow at about 250 milli-amperes.

The oscillating circuit used was the reversed feed back, with the addition of a tuned circuit in the plate lead to power valve. This tuned circuit sharpens up the wave considerably and effects a desirable decrease in plate current.

The main inductance consists of a skeleton hexagonal former, 6" in diameter, wound with 28 turns of 12 S.W.G. bare copper wire, spaced one diameter, and the reaction is a pancake skeleton former, wound with 18 S.W.G., bare copper wire; this is tuned with a variable condenser, maximum capacity ·0003. The grid condenser and plate stopping condenser are each ·002, and made of mica from a smoothing condenser of a B.T.H. generator.

The R.F. choke coil consists of 300 turns of 24 S.W.G., space wound on 4" former. The A.T.I. is fixed well away from all earthed bodies to avoid capacity losses, which at the high radio frequencies used become of great importance.

The shortening condenser used in the aerial calls for some comment. In constructing a condenser for this purpose the following points should be observed. Solder all the plates (which should be of copper or brass) into the supports, and pigtail the shaft by a flexible connection, also the supporting insulation should be kept as far as possible outside the field.

Attention is here directed to the Cardwell condensers (see Q.S.T.), which are designed especially for transmitting circuits.

The remarks regarding the fixing of A.T.I., apply equally to the aerial condenser.

The grid leak is wound to a maximum

resistance of 15,000 ohms, tapped every 1,500 ohms, and is the vitreous type, supplied by the Zenith Co.

Much valuable time was lost in efforts to obtain a suitable synchronous motor to operate the rectifier disc, but the machine was ultimately furnished by the Crypto Co., and has proved most satisfactory in every respect.

The writer wishes to record his appreciation of the valuable assistance afforded to him by Mr. Sharp, of the designers' department of that company.

The speed of the motor is 1,500 r.p.m., when run from 50-cycle supply. It is self-starting, and synchronises in a few seconds of starting up.

The construction of the two-part commutator for the rectifier was a difficult task, in view of the fact that the lathe available had only 3" centres and no back-gear.

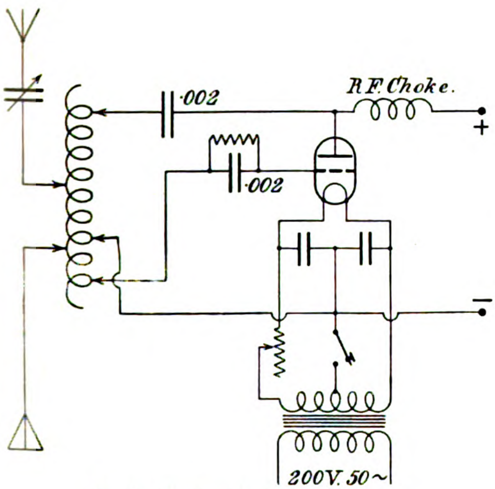


Fig. 4.—Circuit used with AT 40X valve.

As the diameter of the disc is 5" there was insufficient room to use a slide-rest, and in consequence all the turning had to be done by hand tool with a hand-rest.

The insulating core was turned from a slab of ebonite 1" thick, and on this was mounted a piece of 5" outside diameter solid-drawn brass tube, $\frac{1}{4}$" thick (obtained from Messrs. Smith & Son, clockmakers, Clerkenwell), and the tube is screwed to the insulating disc by 12 studs, screwed 3 B.A., the method employed being to tap the hole both in brass

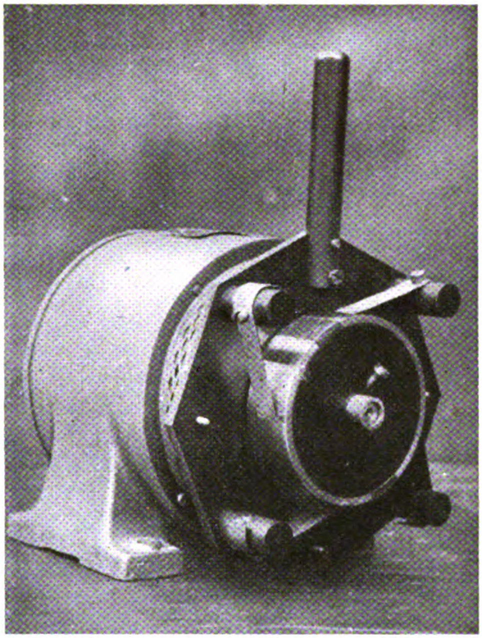


Fig. 5.—Rectifier and brushgear on synchronous motor.

tube and ebonite, and cut off level with surface.

The brass tube is split as shown, and insets of ebonite, or, better, mica on edge, fixed, the whole then being carefully trued up in the lathe. There is also a brass bush with $\frac{1}{2}$"

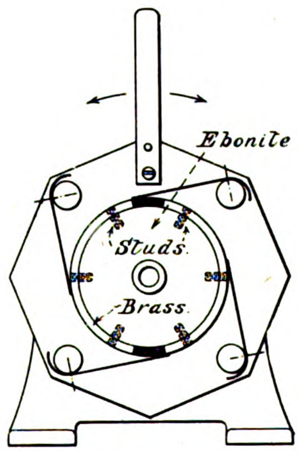


Fig. 6.—Showing arrangement of rectifier disc and brushes.

diameter centre hole and grub screw to clamp the screw to motor shaft.

The insulation between the two sections

must be very good, in order to stand up against the voltage of the transformer.

The brush rocker carries four brush supports 90° apart, and is capable of being rotated by the insulated handle to the position of sparkless commutation.

Brushes are of copper gauze, with the usual supporting strips, and the leads to the four brush holders are of good quality H.T. cable; a short here would be a disastrous thing.

The aerial, built of 12/25 enamelled H.D. copper wire, is a six-wire cage, 70 ft. long, including lead-in, and runs due east and west, being directional for Holland.

The diameter of the cages is 30″ for the horizontal portion, and 18″ for the lead-in, and the position is far from ideal, as can be seen from the photograph, being much screened by adjacent large trees.

The lead-in is through a hole ground out of one pane of glass in the window of the operating room.

As the garden is a very small one the earth screen had to be designed to meet the existing conditions and is a 6″ wire fan, 48 ft. long, average height 10 ft., also of 12/25 enamelled H.D. copper wire; great care was taken to make each wire, both in aerial and earth screen, of equal length. The earth screen terminates immediately under the free end of aerial, although, of course, it is preferable to extend it beyond the garden mast, but there was no available ground to permit of this.

The average experimenter always works under adverse conditions, especially as regards suitable space for an adequate aerial and earth screen, and has to make the best of local conditions.

This station was duly reported in the trans-Atlantic tests, and code verified, but at the time of going to press full details of receptions are not to hand. Apart from that, a long series of regular and consistent two-way tests were carried out with Canadian 1BQ, and shorter tests with U2ACB, also U1CMP, and it is of interest to quote from one of 1BQ's reports: "You are now best European station heard here," and in a later report, "If you want me, just call, as you always come through when any get through."

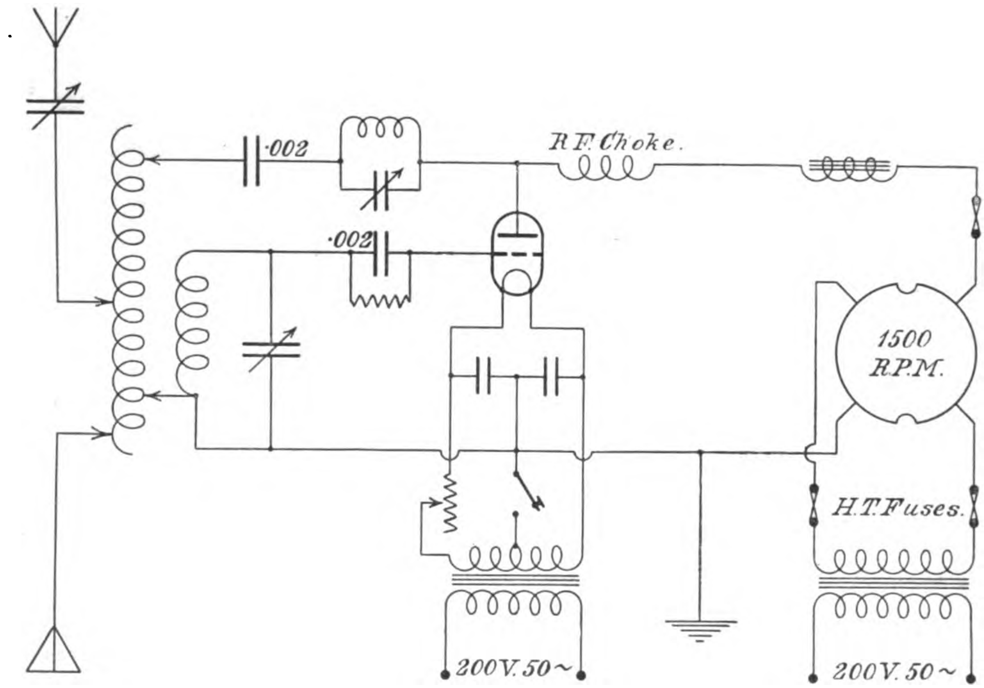


Fig. 7.—Circuit used for 200 metres test, using synchronous rectifier.

French 8AB.

By LEON DELOY.

I HAVE always been very keenly interested in the study of short-wave wireless. My transmitting licence gives me the right to use many waves up to 1,500 metres, and the first transmitter I built worked on that wave. The next one worked on a shorter wave, and so forth until I came down to 100 metres. Every time I decreased the wave-length I increased the range of my station, which was quite contrary to everybody's expectations a few years ago.

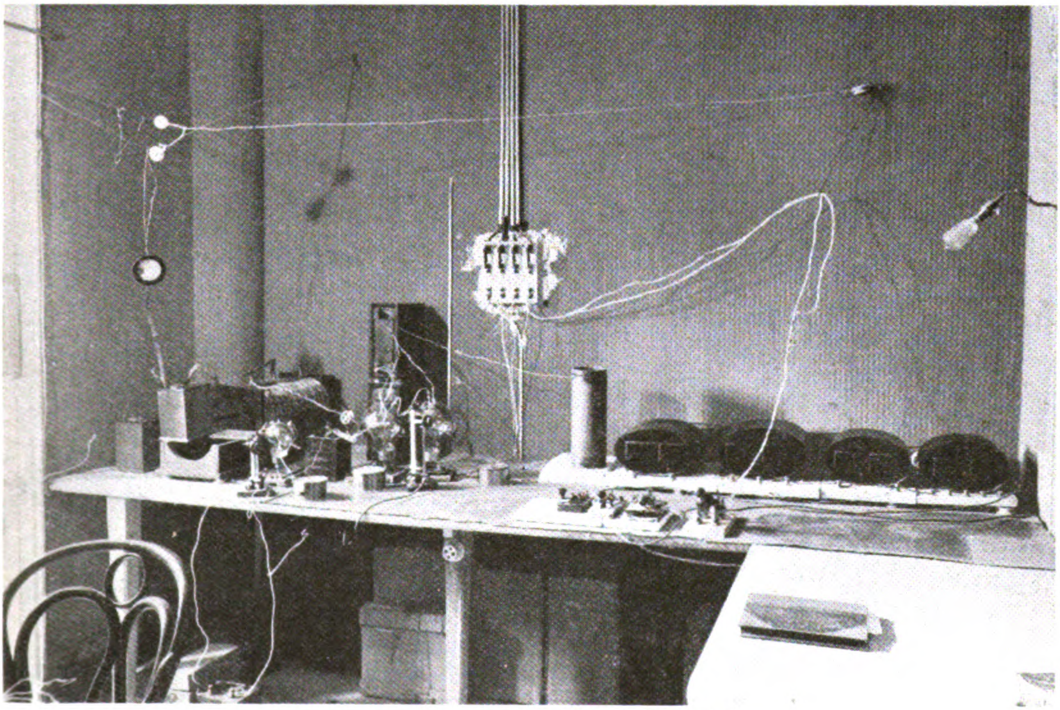


Fig. 1—A general view of the transmitter at F8AB.

On the other hand, I noticed that when the British amateurs were working on 1,000 metres I never heard any of them. When they came down to 440 metres I heard very few of them, but when they were on 360 I started hearing and working them regularly. Now that they send on 200 metres they are very easy to receive, and some of them have been heard at my station in Nice, when they were using exceedingly little power.

During last year's trans-Atlantic tests I used a wave of 190 metres, and I was heard in America " one hour steadily," also several times after the tests, and all the way to Texas. That 190-metre wave was, as far as I know, the shortest one that had ever spanned the Atlantic.

All these and other remarks made me decide to attempt two-way communication with the American amateurs on a wave of 100 metres. During a short trip I took to America this summer I convinced some of them of the interest of the experiment, and Mr. Fred H. Schnell, among others, built a special station to try and communicate with me on that wave. On my return home I dismantled immediately my old station, however good it had proved to be, and re-

built it for 100-metre work. It immediately proved to be a great improvement. For a couple of weeks I conducted nightly tests on schedule, and all reports showed that my signals were much louder than on my old set, in spite of the fact that I was using only half power. I am especially indebted for very regular and accurate reports to Mr. E. J. Simmonds, British 2OD, whose co-operation was very useful in getting the best efficiency out of my set. The reports were so encouraging that I decided to attempt to reach America even before I had re-installed my transmitter for full power. A first attempt was a failure because my correspondent could not believe I had rebuilt my set in so short a time, and he listened for me on my old wave of 190 metres. When this was cleared we tried it again.

I called for one hour on the morning of November 26, calling ARRL, signing F8AB, and sending a code group of five letters to avoid any error in reports of reception. When I woke up late that morning, after a few hours sleep, I found a cable had arrived saying : " COPIED SOLID CONGRATULATIONS." That was quite good news, and I considered it so encouraging that next night I sent a message of greetings in the name of the French amateurs to the American amateurs, and another message about a change of schedule. I asked my correspondent if the new schedule suited him, to " cable agreement." A few hours later a cable was here saying " AGREEMENT ! "

In the course of the same day I had another cable from Mr. Schnell saying he would be ready to transmit on 100 metres the next night, and so it happened that November 28 was to be the long-looked-forward-to day when two-way communication between Europe and America was to be established by amateur stations.

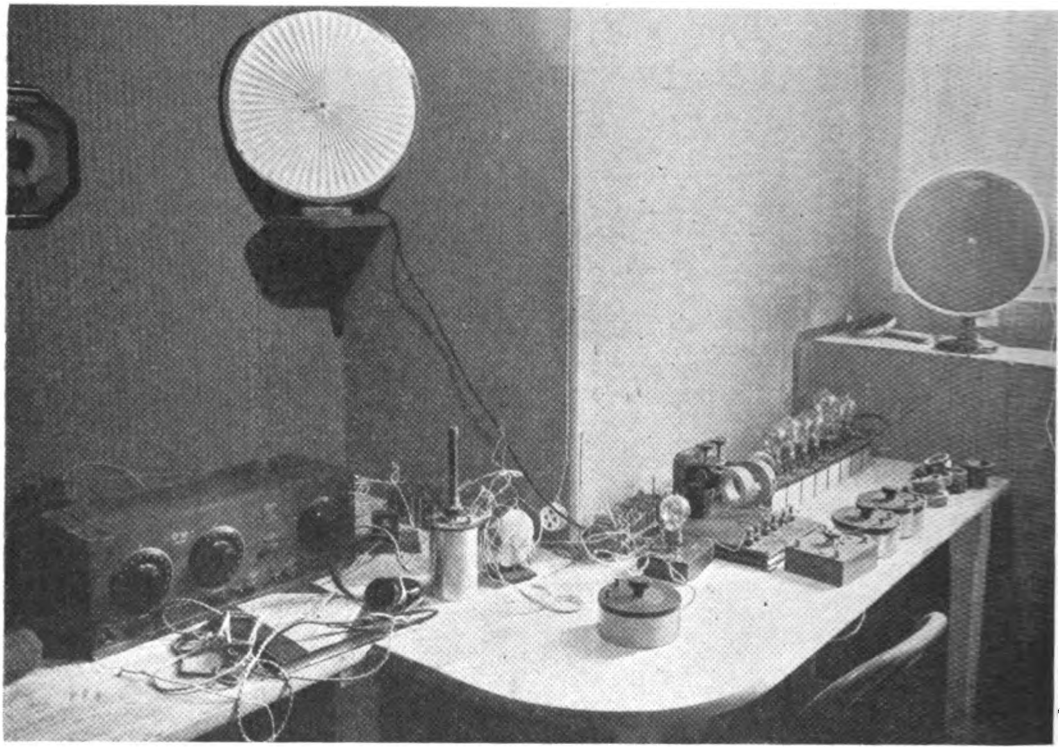


Fig. 2.—Receiver, showing " Grebe " on the left, and home-made super-heterodyne on the right.

On the morning of the 28th I transmitted as agreed, from 0230 to 0330, and then switched over to reception. A few seconds passed, which seemed very long indeed, then came the strong whistling of an A.C. C.W.

signal, and sure enough it called 8AB and signed 1MO! 1MO had again received all I had sent. His signals were readable 6 ft. from the 'phones on two valves, one radio-frequency and one detector. When I said so to him, he came back with: "U ALSO VY QSA TWENTY FEET!! FB!" He has told me since that his receiver uses one detector with tuned plate circuit and one step of low-frequency amplification. We went on talking for a little while as easily as if we were in the same town, although we are about 4,000 miles from each other. Then Mr. Warner took the key at 1MO. His first remark was: "HR WARNER GE OM A PROUD MOMENT OF MY LIFE TO TALK TO U FM MY OWN HOME OM SINCERE CONGRATS ON WONDERFUL ACHIEVEMENT"; and a little later: "MAKING HISTORY TONITE OM." I surely was as glad as they were over there, as this was the reward of three years' work! Then Mr. Schnell took the key again, and said: "SA OM PSE GIVE ME MEG FOR WNP FOR OUR RELAY TEST TOMORROW"; and I sent a message of greetings of the French amateurs to the amateur on board the *Bowdoin*, somewhere near the North Pole. How the world looked small, and how wonderful it is to see far-distant friends become so near just because one has a few feet of wire on one's roof and a couple of glowing valves on one's table!

For the last eleven days I have been in daily two-way communication with American amateurs. About 2,000 words have been exchanged and six stations worked. They are 1MO, 1XAM, 1XAQ, 2CQZ, 2CFB and 1CMP.

A few words about my transmitter may be of interest. I am using two 250-watt (input) S.I.F. French tubes in parallel in a Hartly circuit, with some modifications suggested by Mr. John Reinartz. As will be seen from the accompanying simplified diagram of connections, these modifications are the use of a variable condenser both in the aerial and counterpoise. These two condensers should always be on the same reading, and the counterpoise should be so built that the current in it is the same as in the aerial. The wave-length can then be adjusted simply by adjusting the condensers. The aerial and counterpoise current is between 2·5 and 3 ampères, but I have tried to decrease it, and down to 2 ampères 1MO did not report any appreciable change. When I made it 1 ampère, though, he said it was enough reduction as it became weak. On full power I have been received in America "on 20-ft. indoor aerial," and even "without aerial." My longest range so far reported is Kitchener, Ontario.

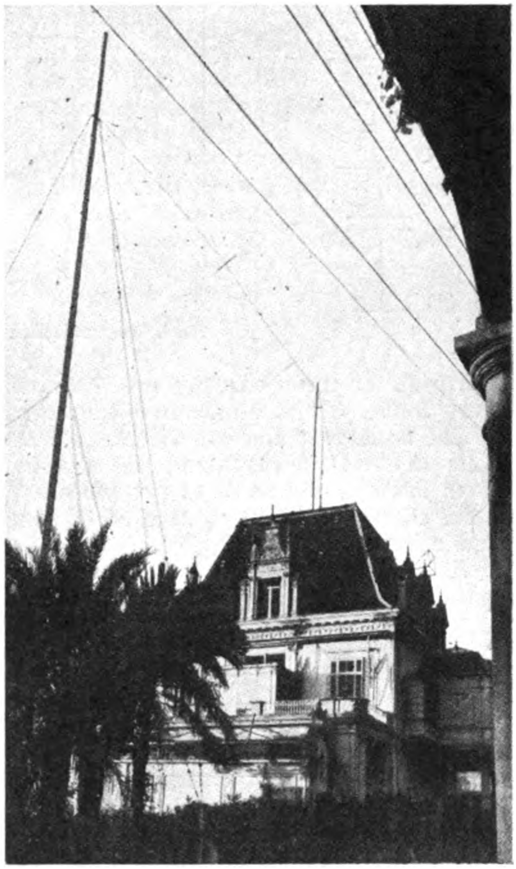


Fig. 8.—Aerial and counterpoise, the far end spreader of the latter being to the right of the palm tree leaves.

The plate high tension is simply furnished from the 25-cycle town supply by a step-up transformer. The filaments had to be heated by batteries instead of A.C. on account of the changes of tension of the supply here. These changes of tension are responsible for the only fading ever noticed during these experiments.

For a grid-leak I am using the plate-filament space of a 50-watt (input) S.I.F. tube. By controlling the filament temperature of this tube one controls the tension on

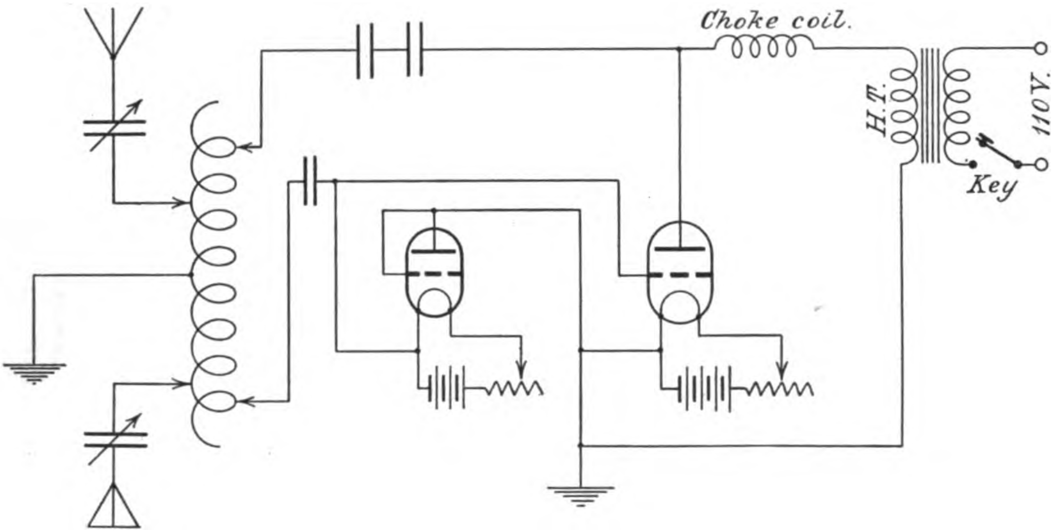


Fig. 4.—The transmission circuit using a valve as a grid leak.

the grids of the oscillating tubes, which is very convenient to obtain best efficiency.

The aerial is a four-wire cage, 10 metres long and 25 metres high; the lead-in is from one end and made of two wires. The counterpoise is similar to the aerial, but a few metres longer.

As will be seen from the accompanying pictures, this set is yet in an experimental stage, and such ranges were certainly not contemplated at such an early date.

The most remarkable point about these tests is that they have shown that waves of the order of 100 metres have wonderful possibilities which were until now almost unsuspected. There seems to be no fading on those waves, and interference, especially from arc harmonics, is very reduced.

Electrical Impulses.

By Dr. N. W. McLachlan, M.I.E.E., F. Inst. P.

Although most experimenters are familiar with the properties of sustained oscillations, the subject of impulses seems to have been neglected. As atmospherics are intimately connected with impulses the following article should be of considerable importance.

An impulsive force in mechanics is one which is communicated suddenly, so that the system or body to which it is applied, *i.e.*, upon which it acts, tends to undergo a rapid change in its state of motion. For example, when the clutch of a motor-car is engaged suddenly, a violent jerk ensues as the car leaps forward under the impulse from the engine. The effect is of a temporary or transient nature, and does not persist when the car is running at a constant speed. Let us take an example in which the impulsed system is capable of vibrating or executing oscillations. Suppose a tuning-fork is struck by a soft-ended hammer. It is set into vibration at its own natural frequency, and the vibration gradually dies away after the blow has been delivered. A pianoforte string under the action of the hammer is another example

of a similar nature. The next case is one in which the system has no natural frequency, because it is so heavily damped that vibrations cannot occur. If a tennis ball is dropped from a height on to some very thick oil, it sinks in to a certain extent and then gradually comes up again. There is no vibration up and down, owing to the fact that the oil damps out vibrations which occur if the ball were dropped on a hard wooden or concrete floor.

It must be clearly realised that the impulsive forces which are called into play do not act merely in an instantaneous manner. They must be applied to the impulsed system for a definite length of time. A change in the motion of a body or a mechanical system due to the type of impulse cited above necessitates a definite supply of energy to the body, and this requires a certain lapse of time to be accomplished. With a force of constant magnitude, the energy added to the system is directly proportional to the square of the time of the application of the force. Thus if one unit of energy is added in one second, four units will be added in two seconds, nine units in three seconds and so on. In general, however, impulsive forces are not constant, and it is often impossible, without definite experimental evidence, to predict their effects to any degree of accuracy.

In treating the problem of electrical impulses, there are two different types of electrical circuit which may be considered: (*a*) one akin to the tuning-fork which will oscillate freely when it is impulsed; (*b*) one like the tennis ball when dropped on the oil, in which vibration or oscillation does not occur, but in which the current merely rises to a certain value, and thereafter dies away to zero. Type (*a*) is the ordinary tuned circuit, either high frequency or audio frequency, with which everyone is familiar in radio-telegraphy. Type (*b*) is obtained if a resistance of suitable magnitude is inserted in a circuit of type (*a*). The effect of the resistance is to apply an electrical damping to the circuit of such a magnitude that oscillations cannot occur. The nomenclature applied to these circuits is respectively "periodic" and "aperiodic." In radio we are not usually concerned with the aperiodic class of circuit, so that our attention will be confined to the usual type, *i.e.*, "periodic" or oscillatory circuits.

An electrical impulse is obtained when a sudden variation in the electrical or magnetic state of space occurs. Such an effect must be distinctly differentiated from a steady train of electro-magnetic waves. One of the commonest instances of impulsing is found with the ordinary buzzer. A buzzer circuit is one supplied periodically by a certain quantity of electricity, which charges the condenser of the buzzer oscillatory circuit. After being energised by the local battery, the circuit executes free oscillations at its own natural frequency, this being determined by the values of the condenser and inductance. When the buzzer circuit is coupled to another circuit which it is desired to tune to the same wave-length, it gives this latter circuit a series of sudden shocks, which in general cause two main sets of oscillations.

Assume the second circuit to be tuned to 400 metres and the buzzer circuit to 450 metres. There will, broadly speaking, be oscillations of both frequencies in the 400 metre circuit, but they will be comparatively feeble. The impulse causes the circuit to oscillate at its own natural frequency, and also forces another oscillation of 450 metres. If now the circuit be tuned to 450 metres, there will be only one main frequency of oscillation, and owing to the effect of resonance, the response or amplitude of the damped oscillation will be a maximum. The value and duration of the current depends upon the duration of each oscillatory discharge in the buzzer circuit, and also on the resistance of the tuned circuit which is being impulsed. If the resistance of the latter circuit were gradually reduced, the effect of an impulse of short duration would become less and less. This is due to the fact that a certain time elapses before the current attains an appreciable value in the circuit. When the impulses are of comparatively long duration, however, the current in the tuned circuit has more chance to build up, and it therefore attains a larger value than before. The magnitude of the current induced by an impulse of given duration depends upon the strength of the impulse, *i.e.*, on the energy supplied to the tuned

circuit. With a low resistance oscillatory circuit in which the damping is small, the time taken after the termination of the impulse for the current to decay to, say, 10 per cent. of its maximum value may be quite considerable compared with the duration of the impulse. Thus if comparatively long impulses follow one another fairly frequently, the current in the tuned circuit will never be zero, and if the impulses are properly timed, the current may attain a large almost steady value. This effect is similar to that obtained with the Marconi-timed disc apparatus used at Stavanger. On the other hand, with moderate impulses, the amount of the energy supply to the tuned circuit is small, and owing to the appreciable time taken for the current to build up, the effect of the impulses is not marked. If, however, the impulses are very strong, there is an appreciable current induced in the tuned circuit. The same reasoning clearly holds for spark reception, since the effect is identical with buzzer excitation of the tuned circuit. Moreover, when receiving spark stations the resistance of the circuits must not be too low. Thus the use of reaction to reduce the resistance of a spark receiver is limited.

We are now in a position to examine the most important form of impulsing which is encountered in radio work, namely that due to "atmospherics." Hitherto no reference has been made to any peculiarities in the shape or wave form of an impulse. If a graph is made showing the intensity of an electrical disturbance at all times during its occurrence the result gives the wave form of the disturbance. It may not resemble an ordinary sine wave at all, but for technical purposes it is convenient to use this terminology. For example, the wave form might resemble a simple rectangle or a simple triangle. Whatever the wave form of the impulse, it is possible by mathematical analysis to resolve it into a series or spectrum of continuous waves of different wave lengths. Before the disturbance starts, these waves, which are really mathematical fictions, are related to each other so far as position (phase) and strength is concerned, so that the net result is zero. After the termination of the disturbance, the same condition also holds. During the epoch or time the disturbance lasts the waves add and subtract so as to yield the actual wave form of the disturbance.

Before passing on to the next phase of the subject, it will be advisable to consider the initial effect of a series of continuous waves of different frequencies on a circuit tuned to the same frequency as one of the series of waves. When the waves arrive originally, say at the beginning of a dot or a dash, the circuit is acted upon suddenly, and the initial effect is in the nature of an impulse. The circuit responds most readily to the waves of its own frequency, but in addition to this the waves of other frequencies eventually force oscillations of their own frequency, and owing to the impulsing effect, they initially assist in augmenting the main or central oscillation. Consider now an atmospheric with its accompanying spectrum or series of continuous waves of different frequencies. The amplitude of some of these may be many times that of the signal, and in addition to impulsing the circuit at its own natural frequency, they introduce oscillations of other frequencies on either side of the central or main frequency. With a strong atmospheric these side oscillations may be much more intense than that due to the signal. The result is that the signal strength is increased when the oscillations add, and it is decreased or increased according to the strength of the atmospheric when the oscillations subtract. In certain cases the signal may be obliterated for a portion of a dot or a dash, and the character is therefore split up into sections, and may be rendered unintelligible. During spacing the effect of the atmospheric is to fill up the gap with dots whose duration depends on the duration and strength of the atmospheric. The atmospheric may therefore be regarded as interpolating an irregular form of jamming.

The inference to be drawn from this analysis is that as many as possible of the frequencies on either side of the central frequency should be eliminated. In this way the energy of the atmospheric which penetrates the receiving system is reduced. The usual mode of cutting out undesirable frequencies is to employ a series of selector or filter circuits, but in the practical radio of to-day there are limitations to the degree of filtering which is possible. Hence the degree of reduction of the atmospheric by this process is also limited.

The Making of Pure Shellac Varnishes.

By J. F. CORRIGAN, M.Sc., A.I.C.

Although shellac varnish is universally employed for wireless purposes the importance of purity is possibly not fully realised. Below will be found details for manufacturing high quality varnish possessing good insulating properties.

SHELLAC varnish, as it is usually prepared, takes the form of a thick, often viscous, and almost opaque liquid which contains many impurities in a suspended or undissolved state. It is easily made by allowing a quantity of flake shellac to soak in rectified alcohol or methylated spirit for a few hours, and subsequently ensuring the entire completion of the solution by warming the mixture. For the " rough " work of wireless construction, such as the varnishing of hidden inductance coils, etc., the above varnish is, of course, eminently suitable, for in these cases it is employed chiefly on account of its insulating and binding properties.

For the purpose of delicately lacquering metal-work, however, and of giving a final layer of insulative varnish to the surface of any coils which may be mounted on the instrument board or the panel of the wireless set or any other type of electrical apparatus, shellac varnish prepared in the above fashion is apt to possess many disadvantages. In the first place, such a varnish does not leave a perfectly smooth surface when dry, no matter how carefully it may have been laid on. Again, the varnish, not being composed of perfectly pure shellac, is apt to be deficient in di-electric properties, and in very accurate work this deviation from the theoretical may sometimes attain serious proportions.

The muddy and opaque appearance of ordinary shellac varnish is really due to the presence in the solution of waxes and fatty substances, which exist as impurities in ordinary commercial shellac to the extent of about 4 per cent. Not being very soluble in alcohol, they remain suspended in the solution, thus causing the turbidity of the latter. However, they can be removed by suitable means, which are about to be described, and if these purifying operations are carefully carried out an alcoholic solution of shellac will be obtained which will present a golden yellow or reddish appearance, and which will be entirely free from any undissolved fatty or waxy substances.

The first method for obtaining a perfectly clear and pure solution of shellac consists in making up the shellac varnish with alcohol or methylated spirit in the ordinary manner, and then adding about an eighth of its weight of precipitated or finely-powdered chalk. The

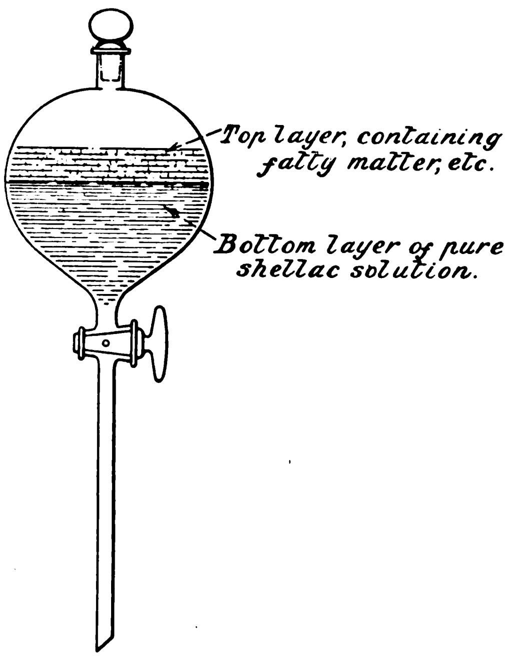


Fig. 1—Showing preparation of varnish.

mixture is then slightly warmed and well stirred, and allowed to remain undisturbed overnight. The chalk will fall to the bottom of the vessel, and will retain the suspended impurities of the varnish, leaving an almost clear solution above. The solution is then carefully poured off from the bottom layer of chalk, and filtered, first through a cloth of fine mesh, and finally through a filter-paper or a sheet of ordinary blotting paper. The use of a vacuum filter pump, such as

is to be found in any chemical laboratory, will greatly facilitate the filtering operations.

Another method by means of which ordinary shellac varnish may be purified consists in adding to it a quantity of petroleum-ether or benzine, in the proportion of one part of the latter to three parts of the varnish. This operation will require the use of a chemical separating-funnel, as shown in the illustration. The liquids are poured into this funnel and, after the stopper has been replaced, they are well shaken up and allowed to stand for about an hour. After the elapse of this period, it will be found that the liquid in the funnel has separated into two distinct layers. The upper and lighter coloured layer of petroleum-ether or benzine, as the case may be, contains the dissolved waxes and fatty matters, whilst the pure alcoholic solution of shellac constitutes the lower layer. If any difficulty is experienced in getting the liquid to separate completely and distinctly, the addition of a few drops of water, together with a further shaking will rapidly bring about the desired end. The lower layer of liquid is now run off by means of the tap which is provided at the bottom of the separating-funnel, and it may be of interest to the radio experimenter carefully to evaporate the upper petroleum or benzine layer and observe the quantity of impurities which have been extracted from the shellac.

Shellac varnish, when prepared by either of the above methods presents a perfectly clear and transparent golden-yellow appearance, and it is free from all undesirable impurities. For accurate, highly-finished, and experimental work its use is greatly to be recommended, because by its employment all the characteristic properties of the shellac are utilised to their fullest extent.

The Trend of Invention.

We summarise below the more important wireless inventions which have been disclosed during the month, special reference being made to those of immediate interest to the experimenter.

Arrangement of Grid-leaks and Condensers in Valve Oscillators.

When the grid condenser of a transmitting valve is connected in the usual way between the grid and the upper end of the grid oscillating circuit trouble may arise if controlling apparatus is shunted across the grid condenser. Such apparatus will be at H.F. potential, and is not only liable to give rise to capacity and leakage losses, but is unsafe for the operator to touch while the set is working. A familiar example is a one-valve grid-control set where the modulation transformer is shunted across the grid condenser, or, again, the system of modulation in which a three-electrode thermionic valve takes the place of the usual grid-leak.

One obvious remedy for this difficulty is to place the grid condenser at the filament end of the grid coil. Another way (British Patent 190,177, G. A. Beauvais) is illustrated in Fig. 1. A separate path B, A, is provided for unidirectional grid currents or modulating currents, a choke B being inserted to keep H.F. currents out of this path and confine them to the proper H.F. path D. Any modulating device is connected in series with, in parallel with, or in place of the resistance A.

The idea of this invention does not seem very new, and, in any case, would occur to any resourceful experimenter if he came across the above-mentioned difficulties.

Electrolyte for Electrolytic Rectifiers or Condensers.

British Patent Specification No. 207,987 (M. A. Codd) prescribes a mixture of sodium bicarbonate and sodium phosphate as an electrolyte for rectifiers. According to the specification the salts may be in equal proportions, or the bicarbonate may be present in excess, about a pound of the mixture being dissolved in one gallon of

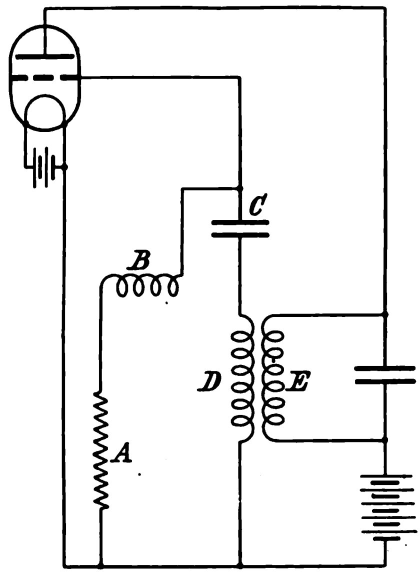


Fig. 1.—Illustrating British Patent 190,177, which covers the use of a grid choke for separating the D.C. from the H.F. components in the grid circuit of a valve oscillator. The choke B is uncoupled with any other H.F. coil.

water. It is stated that four or five pennyweights of calcium carbonate may be added, and also about fifteen grains of a colloid such as gum arabic. The actual functions of the last two substances are not mentioned, but it is stated the electrolyte shows distinct

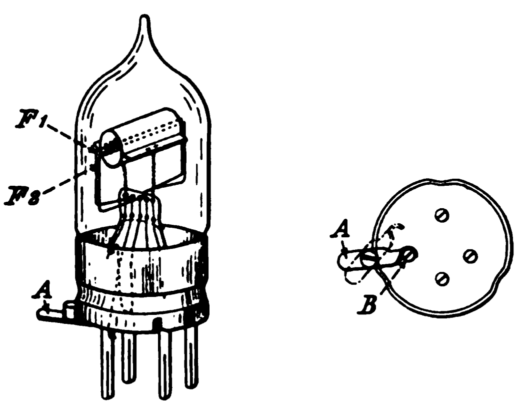


Fig. 2.—Illustrating British Patent 207,740. A spare filament can be brought into play by bringing the clip A into contact with the stud B.

advantages over others in that the heating up is less, rectification continues to take place at a higher temperature, and the plates of the rectifier keep cleaner.

[N.B.—We are not responsible for the archaic system of weights and measures given in the above recipe.]

Valve with Spare Filaments.

Although some of the very earliest round valves were provided with spare filaments to extend their useful life, this practice has not been very widely followed. Fig. 2 shows a recently patented arrangement whereby a valve may be provided with one or more spare filaments, which can be brought into play when desired. When the clip A is in the position indicated by the dotted line the first filament F only is across the filament pins ; by throwing the clip over to the position indicated by the thick line the

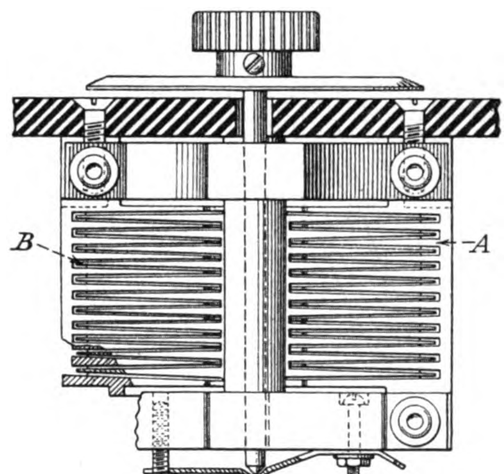


Fig. 3.—Illustrating British Patent 203,660. The radial taper of the plates serves the double purpose of ensuring rigidity and facilitating the removal of the casting in one piece from its mould.

second filament is thrown in parallel with the first (British Patent 207,740, H. C. Phillips).

Condenser Construction.

A good deal of attention is being devoted nowadays to the subject of condenser losses, and especially to the improvement of variable condensers for high-frequency circuits. The construction indicated in Fig. 3 will appeal to the reader as being very sound both electrically and mechanically. (British Patent 203,660, Western Electric Co., Ltd.) The moving vanes and central column B are made in one casting, as are the fixed vanes A. The noval feature lies in the radial taper of the moving vanes. The

fixed vanes also have a corresponding taper in thickness, which leaves an air-gap of uniform thickness between fixed and moving vanes.

Use of Magnetic Amplifier with Valve Transmitter.

Since his invention of the magnetic amplifier, Alexanderson, the American radio engineer, has filed numerous patents involving the use of this ingenious piece of apparatus. Fig. 4 shows the magnetic amplifier adapted to modulate the output of a valve generator. The coils A and B are wound over an iron core, whose degree of saturation is varied by means of a polarising winding C carrying the modulating currents. Thus the effective inductance of the coils is varied, with a consequent variation of resonance of the circuit, including these coils A and B.

It is claimed for this method of modulation that the back E.M.F. from the oscillating valve is at all times nearly equal to that of the H.T. supply, with a consequent maintenance of efficiency when the output of transmitter is at a minimum. It is stated that in most other systems of control that when the H.F. output is at a minimum the conversion efficiency of the valve generator is lowered, and that a consequent heating up of the anode or anodes is liable to take place. (British Patent 186,070, The British Thomson-Houston Co., Ltd., and E. F. W. Alexanderson.)

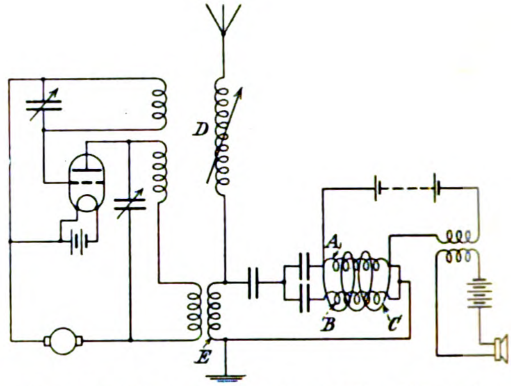


Fig. 4.—Illustrating British Patent 186,070, which provides a means for modulating a valve transmitter without seriously affecting the H.T. input-to-aerial efficiency. The Alexanderson magnetic amplifier is used, and is diagramatically shown by the coils A, B, and C.

Recent Wireless Publications.

Figures after the title of each publication indicate Volume and Number of Publication containing the article. Where only one number is given, this indicates the serial number of the publication. The abbreviations used in this bibliography will be found in the early issues of "Experimental Wireless."

ABBREVIATIONS OF TITLES OF JOURNALS USED IN THE BIBLIOGRAPHY.

Amer. Acad.—American Academy of Arts and Sciences.
Am.I.E.E. J.—Journal of American Institute of Electrical Engineers.
Ann. d. Physik—Annalen der Physik.
Boll. Radiotel.—Bolletino Radiotelegraphico.
Elec. J.—Electric Journal.
El. Rev.—Electrical Review.
El. Times—Electrical Times.
El. World—Electrical World.
Electn.—Electrician.
Frank. Inst. J.—Journal of the Franklin Institute.
Gen. El. Rev.—General Electric Review.
Inst. El. Eng. J.—Journal of the Institute of Electrical Engineers.
Inst. Rad. Eng. Proc.—Proceedings of the Institute of Radio Engineers.
Jahrb. d. drahtl. Tel.—Jahrbuch der drahtlosen Teleg, etc.
Mod. W.—Modern Wireless.
Nature—Nature.
Onde El.—L'Onde Electrique.
Phil. Mag.—Philosophical Magazine.
Phil. Trans.—Philosophical Transactions.
Phys. Rev.—Physical Review.
Phys. Soc. J.—Journal of Physical Society of London.
Q.S.T.—Q.S.T.
R. Elec.—Radio Electricité.
Roy. Soc. Proc.—Proceedings of the Royal Society.
Sci. Abs.—Science Abstracts.
T.S.F.—Telegraphie sans fils, Revue Mensuelle.
Teleg. without Wires, Russia—Telegraphy without Wires, Nijni Novgorod.
W. Age—Wireless Age.
W. Trader—Wireless Trader.
W. World—Wireless World and Radio Review.

I.—TRANSMISSION.

A Constant Frequency Set with a Record.—Capt. T. C. Rives (*Q.S.T.*, 7, 6).

Low-power Loop Transmission.—Oliver Wright (*Q.S.T.*, 7, 6).

Microphone Amplifier and Control Circuits.—Alan L. M. Douglas, M.I.Radio.Eng. (*Exp. W.*, 1, 4).

Aerial Design for 200-metre Transmission.—G. L. Morrow (*Exp. W.*, 1, 4).

Short Wave-length Transmission. The Master Oscillator System.—W. James (*W. World*, 228 and 229).

The Holweck Valve.—(*W. World*, 230).

Commercial Radio Tube Transmitters.—W. R. G. Baker (*Proc. I.R.E.*, 11, 6).

Radio Transmission Measurements on Long Wave-lengths.—H. H. Beverage and H. O. Peterson (*Proc. I.R.E.*, 11, 6).

C.W. and Radiophone Transmitters.—L. R. Felder (*R. News*, 5, 7).

Microphones for Broadcast Purposes.—P. P. Eckersley (*Electn.*, 2,382).

II.—RECEPTION.

Anti-Regenerative Reception.—Lewis Hull, Ph.D. (*Q.S.T.*, 7, 6).

Information on Receiving Tubes. Part I.—J. C. Warner (*Q.S.T.*, 7, 6).

The Design of a Radio-Frequency Amplifier to Operate on a Wave-length Range of 300 to 1,000 Metres.—G. L. Morrow, F.R.S.A. (*Exp. W.*, 1, 4).

Discussion on Loud Speakers for Wireless and other Purposes.—(*Exp. W.*, 1, 4).

A Short Wave-length Receiver with Two Stages of H.F. Amplification.—W. James (*W. World*, 227).

The Fundamentals of Loud Speaker Construction.—A. Nyman (*W. World*, 227).

Some New Ideas in Receiver Design.—F. H. Haynes (*W. World*, 228 and 229).

A French Circuit with some Interesting Features.—(*W. World*, 229).

Galena—Natural and Artificial.—James Strachan, F.Inst.P. (*W. World*, 229).

Discussion on Loud Speakers for Wireless and other Purposes.—(*W. World*, 230).

La protection contre les parasites.—Marcel Bernard (*R. Elec.*, 4, 19).

Receiving Measurements and Atmospheric Disturbances at the Bureau of Standards, Washington, D.C., May and June, 1923.—(*Proc. I.R.E.*, 11, 6).

Recent Developments in High Vacuum Receiving Tubes—Radiotrons, Model UV-199 and Model UV-201-A.—J. C. Warner (*Proc. I.R.E.*, 11, 6).

High-frequency Amplification and its Problems.—R. W. Hallows, M.A. (*Mod. W.*, 2, 4).

Some Notes on Low-frequency Amplification.—G. P. Kendall, B.Sc. (*Mod. W.*, 2, 4).

A Practical Neutrodyne Receiver.—Allan T. Hanscom (*R. News*, 5, 7).

Distortion-free Amplifiers.—A. Ringel (*W. Age*, 11 3).

The Screening of Radio Receivers.—R. H. Barfield, M.Sc. (*El. Rev.*, 2,406).

III.—MEASUREMENT AND CALIBRATION.

The Application of Oscillating Valve Circuits to the Precise Measurement of Certain Physical Quantities.—J. E. P. Wagstaff, M.A. (*Phil. Mag.*, 47, 227).

IV.—THEORY AND CALCULATIONS.

Alternating Currents and Wireless.—Capt. P. P. Eckersley (*Exp. W.*, 1, 4).

An Inductance Calculator.—E. J. Hobbs, M.C., A.M.I.R.E. (*W. World*, 230).

Skin Effect in Slot-wound Conductors.—A. Press (*Electn.*, 2,381).

The Inductance of Coils.—(*W. Trader*, 1, 11).

V.—GENERAL.

Directive Radio-Telegraphy and Telephony.—R. L. Smith-Rose, Ph.D., M.Sc., D.I.C., A.M.I.E.E. (*Exp. W.*, 1, 4).

Frequency Transformers.—H. T. Davidge (*Exp. W.*, 1, 4).

Both-way Amplification.—Alexander J. Gayes (*Exp. W.*, 1, 4).

The "Old Vic" Wireless Relay.—A. G. D. West, B.A., B.Sc. (*Exp. W.*, 1, 4).

Notes on Sources of Energy Loss in Condensers. Part II.—Philip R. Coursey, B.Sc., F.Inst.P., A.M.I.E.E. (*Exp. W.*, 1, 4).

The Construction of a Tuned Reed Rectifier for 200-volt 50-cycle Supply.—E. J. Simmonds (*Exp. W.*, 1, 4).

The Thermionic Rectifier for Battery Charging.—R. L. Smith-Rose, Ph.D., M.Sc. (*W. World*, 227 and 228).

Variable Condensers.—W. James (*W. World*, 227).

The Leafield Imperial Wireless Service.—E. H. Shaughnessy, O.B.E., M.I.E.E. (*W. World*, 229 and 230).

Stationary Waves on Free Wires and Solenoids.—A. Press (*Proc. I.R.E.*, 11, 6).

Digests of United States Patents Relating to Radio-Telegraphy and Telephony. Issued August 28, 1923—October 23, 1923.—John B. Brady (*Proc. I.R.E.*, 11, 6).

The New Low-Filament Current Valves.—A. D. Cowper, M.Sc. (*Mod. W.*, 2, 4).

Break-in Radio Relay Communication.—Col. J. O. Mauborgne (*R. News*, 5, 7).

The Equipment of KDKA.—D. G. Little (*Electn.*, 2,381).

The Beverage Aerial.—T. L. Eckersley (*Electn.*, 2,382).

Untersuchungen unter die Erzeugung sehr kleiner Wellen mit Glühkathenodröhren nach Barhausen und Kurz.—(*Ann. d. Physik*, 73, 1 and 2).

Variable Single Band Acoustic Wave Filter.—G. W. Stewart (*Phys. Rev.*, 22, 5).

The Scientific Applications of Radio-Telegraphy.—Gen. G. Ferrié (*J. Frank. Inst.*, 196, 6).

Radiation. Part XI.—(*W. Trader*, 1, 11).

Les Origines de la T.S.F. (*R. Elec.*, 5, 51).

Pertes diélectriques dans les isolants utilisés pour la construction radioélectrique.—P. Bouvier (*R. Elec.*, 5, 51).

Longeur d'onde optimum.—Léon Bouthillon (*R. Elec.*, 5, 51).

La radiogoniométrie à bord des navires.—(*R. Elec.*, 5, 51).

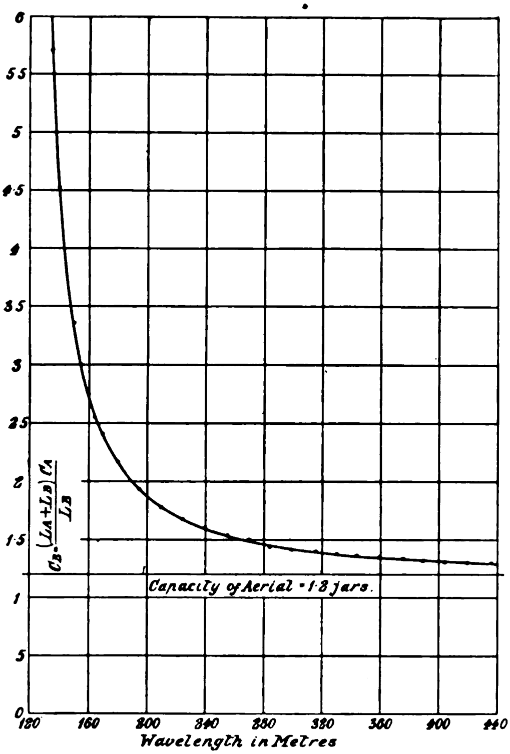
Enroulement à faible capacité propre.—(*R. Elec.*, 5, 51).

Correspondence.

To the Editor of EXPERIMENTAL WIRELESS.

SIR,—The statement that the capacity of an antenna varies with the wave-length used, contained in Mr. Andrewes' article on "Antenna Constants" in your October issue, is not proved by his experiments. The incorrect conclusion arose from the assumption that, for the purpose of the tests, the inductance of the antenna could be neglected.

The curve 1 actually shows that until a point beyond the bend (marked *x* on curve) is reached, the readings of the substitute condenser are valueless as an approximation of the antenna capacity, and that for higher wave-lengths than *x*



they are approaching and approximating to the antenna capacity C_A.

When the condenser and resistance are substituted for the antenna, provided that the inductance added to the closed circuit is small as compared with the antenna inductance, the curve obtained by plotting condenser readings against wave-lengths can be used for obtaining a close approximation to the true capacity of the antenna, which is constant for all wave-lengths; a rough approximation of the capacity of the antenna can be read off once the meaning of the curve is understood; and, finally, a very close approximation of the true value of the antenna capacity can be obtained by calculation from the data furnished by the curve.

Let C_A = capacity of antenna.
C_B = capacity of substitute condenser.
L_A = inductance of antenna.
L_B = inductance added for increasing λ.

AERIAL CAPACITY = 1·2 jars.

Wavelength in Metres.	$L_m C_j$ (mic-jars).	L_m, when C_a = 0·5 jars.	$L_b = L_m - L_a$, where L_a is inductance of aerial (304 mics in this case).	$C_m = \frac{C_a(L_a+L_b)}{L_b} = \frac{L_m C_j}{L_b}$
120	3·65	3·04	0	8
135	4·62	3·85	0·81	5·71
150	5·7	4·75	1·71	3·35
165	6·9	5·75	2·71	2·55
180	8·2	6·84	3·8	2·16
195	9·63	8·02	4·98	1·925
210	11·2	9·34	6·3	1·78
225	12·8	10·67	7·63	1·68
240	14·6	12·15	9·11	1·605
255	16·5	13·75	10·71	1·54
270	18·5	15·4	12·36	1·498
285	20·6	17·15	14·11	1·43
300	22·8	19·00	15·96	1·412
315	24·7	20·58	17·54	1·409
330	27·6	23·00	19·96	1·38
345	29·5	24·6	21·56	1·365
360	32·8	27·4	24·36	1·348
375	35·6	29·6	26·56	1·338
390	38·5	32·1	29·06	1·325
405	41·8	34·8	31·76	1·312
420	44·7	37·2	34·16	1·305
435	48·0	40·0	36·96	1·298
450	51·3	42·8	39·76	1·288

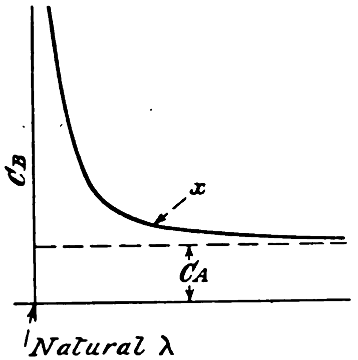
Then $L_A C_A$ represents the LC value for the natural wave-length of the antenna, and its LC value for any higher wave-length is $(L_A + L_B)C_A$; the inductance added to produce any given wave-length is—

$$L_B = \frac{\text{LC for that } \lambda}{C_A} - L_A$$

In substituting a condenser, C_B, for the antenna, some value of C_B is found which, when multiplied by L_B, gives the same product as $(L_A + L_B)C_A$, *i.e.*, $L_B C_B = (L_A + L_B)C_A$ and $C_B = \frac{(L_A + L_B)C_A}{L_B}$.

So the ordinate should read: "Capacity of substitute condenser $= \frac{(L_A + L_B)C_A}{L_B}$," not "Capacity of antenna."

It is obvious that $\frac{C_B}{C_A} = \frac{L_A + L_B}{L_B}$, and that with small loading, the value of C_B will greatly exceed



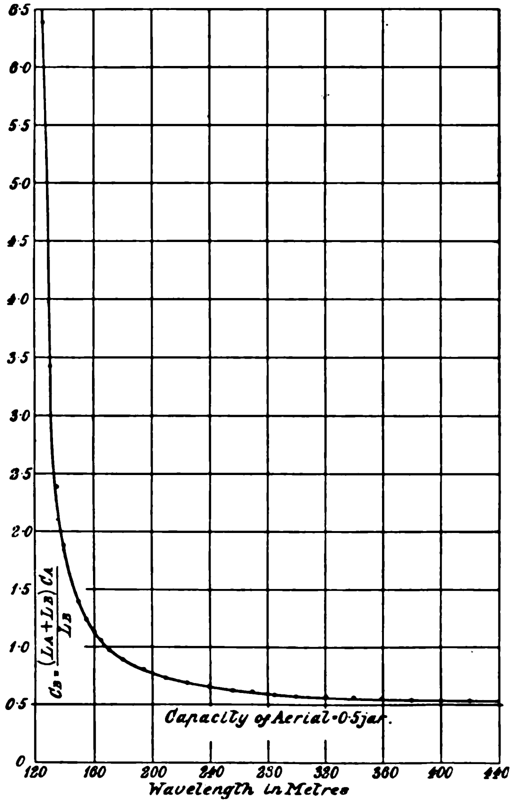
that of C_A; also that these ratios will decrease logarithmically as the wave-length is increased by raising the value of L_B; and that C_B will approximately equal C_A only when the expression $\frac{L_A + L_B}{L_B}$ is approaching unity; all of which is demonstrated by the curve.

I have tabulated the necessary data and prepared two curves showing the variations of C_B with λ, between 120 and 440 metres, assuming in each instance a natural λ of 120 metres, and in the first case an antenna capacity of 1·2 jars, and in the second case 0·5 jars.

AERIAL CAPACITY = ·5 jars.

Wavelength in Metres.	$L_m C_j$ mic-jars).	L_m when $C_a' = 1{\cdot}2$ jars	$L_b = L_m - L_a$ where L_a is inductance of aerial (7·3 mics. in this case).	$C_b = \frac{L_a(L_a + L_b)}{L_B} = \frac{L_m C_j}{L_b}$
120	3·65	7·3	0	∞
125	3·96	7·92	0·62	6·38
130	4·28	8·56	1·26	3·42
135	4·62	9·24	1·94	2·38
140	4·97	9·94	2·64	1·88
150	5·7	11·4	4·1	1·39
155	6·09	12·18	4·88	1·24
160	6·49	12·98	5·68	1·14
165	6·9	13·8	6·5	1·06
170	7·32	14·64	7·34	0·97
180	8·2	16·4	9·1	0·9
195	9·36	18·72	11·42	0·82
210	11·2	22·4	15·1	0·74
225	12·8	25·6	18·3	0·7
240	14·6	29·2	21·9	0·67
255	16·5	33·0	25·7	0 ·64
270	18·5	37·0	29·7	0·625
285	20·6	41·0	33·7	0·598
300	22·8	45·6	38·3	0·595
320	25·94	51·88	44·58	0·58
340	29·3	58·6	51·3	0·57
360	32·8	65·6	58·3	0·565
380	36·6	73·2	65·9	0·555
400	40·53	81·06	73·76	0·55
420	44·7	89·4	82·1	0·545
440	49·0	98·0	90·7	0·54

To calculate the antenna capacity is simple, and based upon the following: The oscillation constant for any wave-length is the product of the antenna capacity and the total inductance; if increasing the total inductance from a to a_1 mics increases the LC value from A to A_1 micjars, then $\frac{A_1 - A \text{ micjars}}{a_1 - a \text{ mics}}$ = capacity of antenna. The procedure then will be to obtain the LC constant for a wave-length,



divide this by C_B, the condenser value, thus giving L_B, the added inductance; take the LC values for the two wave-lengths and subtract them; take the two L_B values found for these wave-lengths and subtract them; divide the difference of the L.C. constants by the difference of the L_B values, and the antenna capacity, C_A, is found.—Yours faithfully,

G. CAMERON MASON.

To the Editor of EXPERIMENTAL WIRELESS.

DEAR SIR,—There seems to be some confusion with regard to effective height and actual height of aerials, as judged by recent correspondence in your columns. May I point out that the formula

$$R r = 160\pi^2 \left(\frac{h}{\lambda}\right)^2$$

takes account of the *actual* height, and not *effective*

height; it is subject to correction by a "form factor" for certain types of aerials, but this is so near unity for all ordinary antennæ that it makes no practical difference. The formula is, I believe, an empirical one, based on actual measurements, and, therefore, incorporating the correction for effective height; thus, if we introduce effective height, found in another way (or estimated), we lay ourselves open to large errors by introducing a correction twice. The fact that Mr. Hogg's measurements agree so nearly with the calculated value, assuming $h=28$ ft. should help to decide the controversy. This formula and a table and worked example may be found in Hoyle's "Standard Tables and Equations in Radio Telegraphy," by those caring to follow the matter up. There are, of course, further losses in trees, masts, etc., which are sometimes included, sometimes added as correction factors, in various formulæ for effective height, radiation, and so on; other writers, again, put these losses down to actual transmission (wave), and many pitfalls of the kind exist for the unwary. In all these cases it is necessary to keep a sharp look-out, as a correction may be included three or even four times, with obviously fatal results.

Passing to other letters, may not Mr. Ryan's better results with thick wire be due to its *greater* damping effect than to less resistance compared with moderately thin wire? Greater surface area may be more than nullified by more eddy current losses. "Better" results do not necessarily mean greater signal strength. I do not like to drag in trade matters, but it is almost necessary to illustrate my point. The most scientifically designed plug-in coils on the market are those sold by Messrs. Gambrell Bros.—due, I believe, to Mr. Onwood. For a given inductance they go much lower than other coils, even single layer-types, owing to their very small self capacity, and I have found that signals are clearer and more sharply tuned on these coils than on any others—and I have made some hundreds of comparisons, usually with a high resistance crystal (carborundum), and no reaction to upset the damping. (Let me disclaim any connection with the firm in question at once.) Now the short wave coils of this series are wound with finer wire than some of the long wave ones; A, B and C appear to be wound with 28 or 30 S.W.G., whereas E has 22 S.W.G.; a designer producing a series of coils with so many evidences that he knows his subject would not be likely to neglect a study of optimum wire sizes. I am afraid, then, that I must disagree with Mr. Ryan and affirm that the H.F. resistance of a comparatively fine wire may be less than that of a thick wire, and this difference is accentuated in the case of a coil. As to the controversy which has always raged round "litz" wire, I do not want to open up that, so will do no more than mention it.

In the matter of the heterodyne, I beg leave to change sides, and differ from Mr. de Burgh. It does not matter what proportion the rectified current bears to the unrectified; if, before rectification we have the amplitude of the beats in one case greater than they are in another, then the rectified current will be greater. To get loud signals, it is necessary to get the maximum amplitude in the beats produced, and there is only one way of doing this, that is, the incoming oscillations and the local heterodyne oscillations must be of *equal* amplitude at the point of introduction of the latter. If the local oscillations are either stronger or weaker than the incoming signals the beat amplitude suffers, and the resultant in the telephone is weaker. Taking the case where the local currents are weaker than the incoming, we have greater selectivity on weak signals, as a strong signal cannot make more noise than a weak; on the other hand, in the more common case where the local oscillations are more powerful than the incoming, signal (telephone) strengths are proportional to the incoming signals only—whether directly or as the square or root or what not makes no difference, the strong signal wins every time. The effect on the detector action mentioned by Mr. de Burgh could be likened to a sort of wipe-out artificially produced, and does not seem to increase the *variation* in telephone current at all; it would be much more logical to put in some H.F. amplification and control the grid potential to get an almost similar result. I cannot quite see how this action would apply in the case of grid-condenser rectification, as we do not reckon to work on either of the bends of the curve in that case, and the whole arrangement would suffer from the wipe-out effect of a strong local oscillation. In dealing with weak C.W. practically I have always found it of advantage to use a heretodyne with a very small coil and large condenser—the latter giving a wide λ range on the one instrument, and the former having a very small field, rendering possible the adjustment of the heterodyne as to strength without having to place it six feet away or in another room to come down to weak signals. As a detector a valve of the universal type (R, ORA, V24, etc.), with leaky grid condenser, works well on weak signals when used with a weak heterodyne as well. (For spark and telephony, on the other hand, a valve such as the Q, with controlled grid, or a crystal, will give purer tone, but this is by the way.)—Yours faithfully,

LEONARD J. VOSS.

To the Editor, EXPERIMENTAL WIRELESS.

DEAR SIR,—Referring to the article in the December issue of EXPERIMENTAL WIRELESS on "General Efficiency of Reception on Short Waves," we should like to draw your attention to a statement made by the author which may prove a little misleading to your readers. The author states: "The universal fault with all short wave plug-in coils on the market is that the wire used is far too thin. All coils for short wave work should be wound with at least 18 or 20 gauge."

It is not always realised that the D.C. resistance of coils due to the wire gauge is often negligible in comparison to their effective resistance at high frequencies. For example, a type of coil which may be suitable for high wave-lengths and has a D.C. resistance of two to three ohms, may on low wave-lengths have a resistance of between two and three hundred ohms.

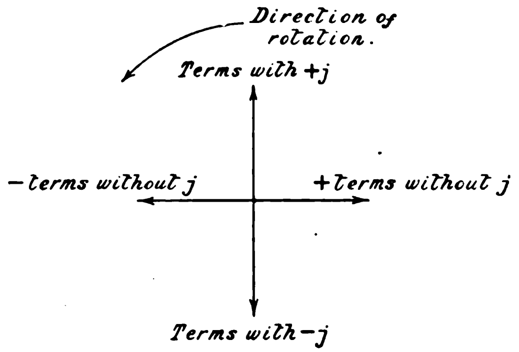
It follows, therefore, that the important point is not the size of the wire, but the design of coils. It is important that no two turns in the coil should come into contact with each other, whether well insulated or not. Coils wound in such a fashion

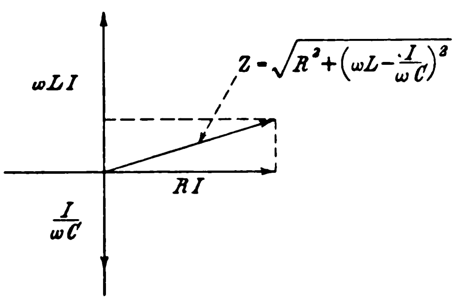
that the turns cross each other are not suitable for very low wave-lengths, as their losses at these frequencies are very considerable.—Yours faithfully,

GAMBRELL BROS., LTD.,
R. Annan, *Sales Manager.*

To the Editor, EXPERIMENTAL WIRELESS.

DEAR SIR,—It was indeed gratifying to read in the current issue of EXPERIMENTAL WIRELESS the article by Capt. P. P. Eckersley on "Alternating Currents and Wireless." To educate the student of wireless to the use of j is, indeed, a worthy step in the right direction.





There are one or two points, however, which I should like to mention. First is it rather unfortunate that your contributor has adhered to the old-fashioned symbols, *e.g.*, C and not K is now used to indicate the capacity of a condenser, and *w*, not *p*, is more usual and preferable to the modern student. Again, in indicating the method for calculating the value of the R.M.S. current I, no mention is made of units. This is a serious omission, for it leaves the experimenter in doubt as to what substitutions to make—shall it be micro-henries or henries, etc. ?

E (R.M.S.)	should	be measured	in	volts.
I (R.M.S.)	,,	,,	,,	amperes.
R	,,	,,	,,	ohms.
L	,,	,,	,,	henries.
C (or K)	,,	,,	,,	farads.
Z	,,	,,	,,	ohms.

When drawing vector diagrams it is essential to indicate the assumed direction of rotation for the vectors, and, according to modern practice, this is anti-clockwise—this is another omission.

The reason for the use of j is simply explained. Multiplying a vector by = 1 turns it round through 108°, *i.e.*, it points in the opposite direction, so that in order to turn it round through 90° it is multiplied by $\sqrt{-1}$, so that the two movements of 90° are secured by $\sqrt{-1} \times \sqrt{-1} = -1$.

Multiplying the vector by $\sqrt{-1}$ causes it to lead 90° on its previous position, and not lag, as stated by Capt. Eckersley, so that his diagram should be as shown. The numerical result is the same in each case, but confusion will arise if the value of the phase angle is required.—Yours faithfully,

H. J. BARTON CHAPPLE,
Bradford Technical College.

To the Editor of EXPERIMENTAL WIRELESS.

DEAR SIR,—I beg to submit a few results of experiments conducted upon the 4-circuit tuner. The set was constructed exactly as detailed in the first issue of EXPERIMENTAL WIRELESS, with one marked exception. During the experiments it was noticed that the tuning of the aperiodic aerial coil "A" seemed relatively sharp. As the stator of a tapped variometer was being used for this coil, the rotor was naturally included, with the result that the set was easily brought to the point of sub-oscillation accompanied with marked increase in signal strength. Upon an indifferent P.M.G. aerial averaging 25 ft. in height, all the Broadcasting stations were received, 2LO, 15 miles away, at nearly loud-speaker strength, and the more distant ones, comfortable strength on 'phones. With one stage of L.F. London worked a loud speaker easily, whilst 2NO, 5SC and several others were at about R.6 signal strength. Upon an indoor aerial 20 ft. long at an average height of 9 ft., London was received at R.5 on two valves, which is remarkable under the circumstances. With regard to re-radiation, I can state that this is nil, by corroboration with a friend using a big set at 700 yards distance.

I should earnestly advise any experimenter to make up this set, which is chock-full of possibilities, and shall be pleased to help anyone who would wish further particulars. Wishing your splendid journal the best of success, and thanking you for the opportunity of learning such a lot from it.—I remain, yours sincerely,

H. J. WYATT.

Business Brevities.

Two New Receiving Valves.

A type of valve which is well known to the Canadian experimenter as the Myers Valve has recently been placed on the market by Messrs. Cunningham and Morrison, 49, Warwick Road, S.W.5. Two types are being made, one consuming about a quarter of an ampere at four volts, while the other operates at about two to two and a half volts. We have tested both types, and find them to be very good from all points of view. The two-volt valve, besides being tested on signals, has been examined in our laboratory, and the results of the test are summarised briefly below.

A characteristic curve is given, and it will be noted that the "straight" portion is practically

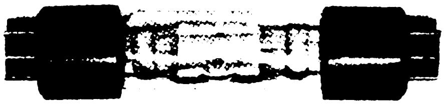


Fig. 1.—The Myers receiving valve.

straight over almost its entire length. A set of curves were taken, and gave an amplification factor of 8.6, which, in conjunction with an anode filament impedance of about 50,000 ohms, should indicate a useful performance for general work. On test it was found to be an efficient rectifier, and also capable of dealing with a considerable load as an audio frequency amplifier, the saturation current being quite large. It was also found to be a quite good radio frequency amplifier, and its function in this capacity is, no doubt, assisted by a fairly low self-capacity, due to the method of construction. A general appearance of the valve can be gathered from the accompanying photograph, which indicates the special type of connection to the electrodes. A set of clips for mounting is supplied with each valve, together with a template for marking out the panel. The method of construction results in a very strong valve, which, at the same time, is very free from microphonic noises. The Myers valve should readily find a place amongst every experimenter's equipment.

* * *

A Gambrell Wavemeter.

Messrs. Eustace Watkins, Ltd., have sent us for test a standard Gambrell wavemeter, an illustration of which appears on the next page. It is one of the nicest crystal-buzzer wavemeters which we have seen and it is extremely convenient to handle. The arrangement consists of a small polished box with an ebonite panel on which are mounted the variable condenser, crystal rectifier, buzzer and telephone or battery terminals and two-way switch. The inductance is not included in the case itself, but a coil holder is mounted on the panel into which various Gambrell coils can be plugged. The normal range of 100 to 8,000 metres is covered with only four coils. The Gambrell air spaced coil it will be remembered has exceedingly small losses, the self-capacity being very small. With a given condenser, therefore, it is possible to cover a considerable range of wavelengths; and at the same time the tuning is fairly sharp. The calibration curves supplied with each instrument are checked against National Physical Laboratory Standards and on test we found them to be quite accurate. The crystal rectifier is of the perikon type and has a moderately high resistance which ensures fairly good resonance in the oscillatory circuit. On the transmission side, the circuit is excited by means of a high note buzzer which gives a group frequency of about 1200. The note is extremely clear and penetrating. The decrement of the circuit is very good as the maximum point of resonance is very clearly defined. Finally we can unreservedly recommend the instrument to any experimenter

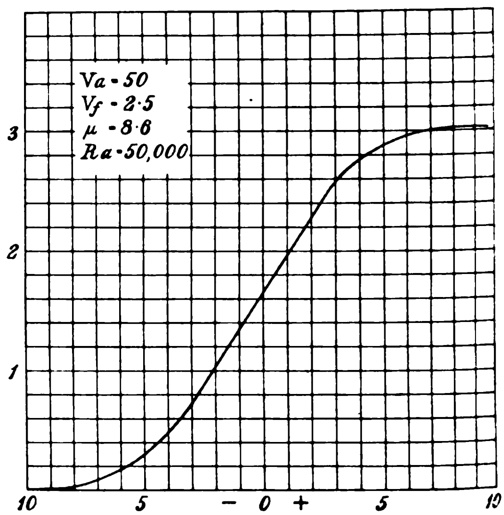


Fig. 2—Characteristic curve of the Myers valve.

who is contemplating the purchase of a wavemeter. The price including four coils and calibration curves is £7 15s., and the London agents are Messrs. Eustace Watkins, Ltd., 91, New Bond Street, London, W.1.

* * *

Marconi Scientific Instrument Co., Ltd.

The Marconi Scientific Instrument Co., Ltd., have recently issued a new brochure relating to their receivers specially designed for broadcast reception. A speciality is a line of three- and five-valve receiving sets mounted in handsome cabinets designed to tone in with furnishing schemes of various periods, such as Jacobean, Queen Anne and Chippendale. The circuits are such as to be suitable for receiving long wave continental broad-

casting in addition to local short wave programmes. In addition to broadcast receivers we note that single and two-valve note magnifier are shown and also a compact transmitter, details of which apparently vary according to requirements.

* * *

PETO SCOTT'S WIRELESS BOOK.

We have just received from The Peto Scott Co., Ltd., "Peto-Scott's Wireless Book" which is best described as a combined catalogue, instruction and circuit book. The first part of the book is devoted to some general ideas on broadcast reception and gives advice to the beginner on all subjects ranging from the most suitable type of aerial insulator to the correct way of soldering. The last few pages of the book are devoted to circuits and chiefly illustrate the proverbial tuned anode with reaction together with one or more audio frequency amplifiers. Various dual circuits, of course, are also included. The middle section of the book, however, is likely to interest the advanced experimenter. Here will be found full particulars of the Peto-Scott "Unettes." They consist essentially of the usual variety of components each mounted on ebonite together with terminals and perhaps we cannot do better than quote from their own description :—"Panels are of uniform size. The input for the component is arranged on the left-hand side, and the output on the right, so that any component can be coupled to the preceding and following component by simply cross connecting the terminals which become opposite to each other. The variable condensers are shielded from dust and the two sizes used for tuning have extra terminals placed on the base, so that by giving the whole base a quarter turn the connections are automatically reversed from series to parallel, and *vice versa* (Pro. Pat. 21,798). All coupling panels are provided with an extra terminal so that grid control can be arranged without altering the standard wiring of these panels. Separate terminals are provided for each plate circuit so that the correct H.T. voltage can be applied to each anode. A stand-by-tune switch is provided on the three-coil tuner. Reaction can be applied to primary, secondary or tuned anode circuits as desired. Specially shaped end pieces, and also blank panels are provided so that the "Unettes" can be arranged in a double or treble bank. For further facilitating the connections from panel to panel, instead of the usual type of terminal, the special spring terminals, known as "Refty terminals" are fitted to all these panels. These terminals have ridged contact surface, and all you have to do is to press—insert wire—leave go—and you have a secure mechanical and electrical connection which cannot shake loose. . . . The panels are of best quality ebonite ⅜ in. thick, recessed on the under-side so that the wiring can be neatly carried out and concealed, and comprise three sizes, large 4¼ by 4¼ ins., medium 4¼ by 2⅛ ins., and small 4¼ by 4¼ ins. The components are mounted on a large, medium, or small panel, and the medium and small-size panels together are the same size as the large." It seems that these components should be of considerable value to the experimenter who has a variety of circuits to arrange as they can be screwed on to a board and all connections made above, without the necessity of drilling holes and removing wood to clear wires coming from below. In passing we may mention that "Unettes" are marked "Prov. Pat. No. 23419." Exactly what is claimed will be interesting to note as at present the subject matter of the patent is not very clear.

* * *

THE WIRELESS ANNUAL.

"The Wireless Annual for 1924," published by the Wireless Press, Ltd., is one of the most useful and dependable reference books which we have seen for some time. The first part of the book is devoted chiefly to articles which in themselves reflect the progress that has been made during the preceding year, both by the professional and amateur. Of great interest is an article by Senatore Marconi, which gives constructional data for an extra high-frequency oscillator and receiver. Perhaps of most value to the advanced experimenter is the very extensive collection of practical data necessary for any serious design work. Amongst other items is an alphabetical list of call signs of the world and also a directory of amateur calls in Great Britain and France. Another interesting feature is a list of Radio Manufacturers which should prove very useful. The comprehensive nature of "The Wireless Annual" which is priced at 2s. 6d. should readily secure for it a place on the bookshelf of every radio enthusiast.

Fig. 8—The general appearance of the Gambrell wavemeter. Note the ebonite extension handle which slips into the lid when not in use.

* * *

GRIFFIN WIRELESS SUPPLIES CO.

Messrs. Griffin Wireless Supplies Co., of 80, Newington Causeway, have asked us to announce that they have now opened a branch at 18, Kingsland Road, E.2, which they think will be more convenient for many of their customers.

* * *

MESSRS. BERTRAM DAY & CO., LTD.

Messrs. Bertram Day & Co., Ltd., the well-known wireless advertising agents, inform us that once again the extent of their business has compelled them to take larger premises and the new address of the Service Department is now No. 1, Charing Cross, London, S.W.1.

"THE MODEL ENGINEER" EXHIBITION.

At the seventh annual *Model Engineer* Exhibition held at the Horticultural Hall from January 4-11 some seven wireless firms were represented including the Bowyer-Lowe Co., Ltd., Will Day, Ltd., Economic Electric, Ltd., Grafton Electric Co., W. Jones, Peto-Scott Co., Ltd., Wainwright Manufacturing Co., Ltd. Following so closely upon the Wireless Exhibition there were very few instances of new developments of any considerably importance. We noted, however, a very compact valve holder and rheostat of the wood mounting type by the Bowyer-Lowe Co., Ltd., which should prove very useful. The Patent Die Castings Co., Ltd., were showing a set of cast name plates of the usual series and should look very neat when mounted on a panel.

Experimental Notes and News.

NEW WIRELESS STATION OPENED IN ARGENTINA.

The new wireless station which has been built at Monte Grande for the Transradio Internacional Compania Radiotelegrafica Argentina for the purpose of placing the Argentine in direct wireless communication with North America, Europe, and the Far East, was recently opened, when an inaugural message was sent from the President of the Argentine to King George V. Direct services will be carried out between Monte Grande, New York, Paris, and Berlin. It is intended to extend this direct service to England as soon as possible, but as Great Britain does not possess a wireless station sufficiently powerful to communicate with South America this service cannot be brought into operation until a suitable station is available in this country.

The transmitting station at Monte Grande, 20 kilometres from Buenos Aires, covers an area of 1,200 acres. There are ten steel towers 500 metres apart, each tower being 690 ft. high. The power of the station is 800 k.w.

The receiving centre is at Villa Eliza, 39 kilometers from Buenos Aires and the same distance from the transmitting station.

The telegraph office, from which the transmitting station is automatically controlled and to which the receiving station is connected with telegraph lines and an automatic linking device, as is the case in the Marconi system in this country, is situated in the centre of the commercial quarter of Buenos Aires.

In addition to the message sent to the King, Senor Don Marcelo T. de Alvera, President of the Argentine Republic, sent the following message to the Chiefs of the States of the World, through the new Monte Grande Wireless Station :—

> The President of the Argentine Nation at the inaugural ceremony of the Monte Grande High-Power Wireless Station expresses wishes for the prosperity of all the nations of the world. In doing so he interprets the characteristic and traditional feelings of universal brotherhood held by the Argentine people who are desirous of feeling themselves always in solidarity with all these peoples who are struggling for peace and civilisation.

* * *

AMATEUR TRANSMISSIONS IN THREE LANGUAGES.

It will be of interest to readers to know that the well-known French amateur, of Transatlantic tests fame, Dr. Pierre Corret, of Paris, has lately been sending out Morse transmissions under the call sign of "8AE2." He works at 11 p.m. on Monday, Tuesday, Thursday, and Friday of each week, and he sends out the following message in French, English, and Esperanto :—

> "Wireless amateurs who hear these signals, are requested to be good enough to report to Dr. Corret, 97, Rue Royal, à Versailles, Paris, how these signals have been received."

Dr. Corret first gives the general call "CQ de 8AE2" then the call in French, English, and Esperanto Wave-length 200 metres. We trust that this little experiment will meet with the success it deserves.

* * *

RELAY STATION AT PLYMOUTH.

The British Broadcasting Company has received a permit from the Postmaster-General for the erection of a wireless relay station at Plymouth. Operations will be begun as soon as possible, and it is hoped the station will be working in two or three months.

* * *

NEW STATION FOR HELP OF FISHERMEN.

In the course of the next few weeks another of Europe's northerly wireless stations will be completed at Vardoe, in the extreme north of Norway. The station will be of moderate size, but fitted with all the most up-to-date instruments, including a wireless telephone. The transmission radius will enable it to maintain communication with Spitzbergen in the north and with Fauske station in the south. The masts are each 59 metres high. The Vardoe Station will assume a position of importance in view of its situation with regard to the trawling fleets engaged in Arctic waters—along the north coast of Norway or in the region of the Shetlands. Weather and other reports of usefulness and interest to the fishing fleets will be regularly sent out.

* * *

THE 5SC STATION.

Information has reached Glasgow that wireless transmissions from the broadcasting station in that city has been picked up at Flandreau, South Dakota, United States, and by four receiving stations in Minneapolis. The distance from Glasgow to Flandreau is approximately 4,750 miles. A reading and musical selections were clearly heard. London 2LO has also been heard at Camps Bay. On a loud speaker dance music was audible 15 yards from the instrument. Within about two months the British Broadcasting Company hopes to give an international evening with music from such places as Paris, Brussels, and an American station.

Experimental Wireless

A JOURNAL OF RADIO RESEARCH AND PROGRESS

VOL. I, No. 6. MARCH, 1924. 1s. NET.

Experimental Topics.

Price Cutting in Wireless Goods.

The business of selling wireless goods has developed at such an enormous pace during the last year or so, that it is not surprising to find it marked by certain abnormal and, in some cases, undesirable features. All sorts and conditions of people have jumped into the New Eldorado of wireless trading, determined to exploit the enthusiasm of the public for the benefit of their own pockets. It is no uncommon thing to see wireless goods exposed for sale in the shops of stationers, hairdressers, pawnbrokers, second-hand furniture dealers, and many other traders whose normal business does not call for the slightest scientific or technical qualification. It may be that here and there among these folk is one who as a very keen enthusiast has studied wireless to some good purpose, and is competent to judge the quality of the apparatus he is selling and to advise purchasers honestly and well. But we fear that the majority of such traders, however, well-intentioned they may otherwise be, fall sadly short in the technical knowledge which is necessary to sell wireless goods with advantage to the customer as well as profit to themselves. Misrepresentation of goods, or the sale of unsuitable goods, whether unintentional or not, cannot but lead to disappointment of the public, and to injury to the wireless industry as a whole. This is only one of the difficulties from which the wireless industry is suffering; a far more serious matter is the epidemic of price-cutting which has recently set in. It is a matter of common knowledge that there are firms who have no regard for the prices of standard goods fixed by manufacturers, but "cut" these prices without compunction in order to attract the bargain hunter. We say unhesitatingly that this is a practice which is contrary to all fair-trading principles, and we ask our readers not to lend it their support. It should be clearly understood that we are not arguing against fair competition, however keen it may be. We are not advocating the maintenance of high prices, nor are we expressing any approval of "profiteering." On the contrary, any fair competition amongst manufacturers or retailers which results in more favourable prices for the consumer without sacrifice in quality is to be whole-heartedly commended. But we contend that any manufacturer is entitled to fix the prices at which his goods shall be sold to the public. He takes the risk of his price being acceptable to the public, and he takes the risk of a rival manufacturer offering an equally suitable or a better article at a lower price. If he finds his competitors are beating him out of the market he must improve his manufacturing methods, or be content with a lower margin of profit, and meet the competitive prices. That is fair competition and is all to the good from the consumer's point of view. Whatever price, however, the manufacturer

does place on his goods, he is entitled to have respected by his agents, and by the retail trade in general. Price-cutting of the kind indicated is very disturbing and very unfair in various ways. The manufacturer may find in a paper alongside his own advertisement, another advertisement from a price-cutting firm, of his own goods offered at considerably reduced prices. One of his own retail agents may find his stock almost unsaleable, because a shop round the corner is offering the same goods at "cut" prices. The obvious remedy of refusing supplies to the price-cutting firms is only a partial remedy; by various devious methods they manage at present to secure a sufficient stock of goods of standard make to enable them to shout about their "cheap" prices. No doubt in time all sources of supply will be closed to them, as has been successfully done in other trades where similar price-cutting tactics were adopted, and then the industry will be freed from what is a growing and an objectionable practice. The reputable manufacturer who believes in the maintenance of a fair price for his goods, backs his price with the guarantee of good quality and good service. A customer buying standard goods direct from the maker, or through an accredited agent, knows that he will get a perfect article, or, if not, that any defective article will be replaced or made good. There is fair service behind a fair price. There is no such service behind a "cut" price; the manufacturer does not stand behind the price-cutter as he does behind his accredited agent, and this fact alone should make wireless experimenters cautious in their purchases. The experimenter cannot afford to have his work go wrong because of defective apparatus or material; it wastes valuable time as well as money, and a "cut-price" purchase may well prove to be anything but a bargain in the long run.

Amalgamation.

After many months of negotiations and renewed negotiations peace seems to reign in the amateur transmission world. At the last meeting of the Radio Transmitters' Society the motion that the Radio Transmitters' Society should amalgamate with the Transmitter and Relay Section of the Radio Society of Great Britain was carried by a substantial majority. The meeting, however, was not uneventful, as several speakers seemed strongly opposed to co-operation, but while, perhaps, their arguments were quite logical, we think that co-operation is the only satisfactory solution to the problem. Not only should the combined forces of the two societies give greater strength to the amateur position, but the amalgamation should prove mutually beneficial. We wish the new body every success, and trust that they will do much to further the amateur movement.

Concerning Calibration.

The scores of variable condensers, wavemeters and other instruments which have passed through the calibration department of the EXPERIMENTAL WIRELESS Laboratory during the last few months have provided much food for thought. We begin to wonder if the meaning of calibration is really fully appreciated by the radio enthusiast. Perhaps a few words of advice to those who are contemplating forwarding apparatus may be of value, as many instruments which have found their way to the laboratory have been immediately returned for mechanical alterations before calibration has been possible. Variable condensers, perhaps, are the worst offenders. It is quite common to receive a condenser which shorts over some 50 or 60 degrees of the scale, while condensers without a zero mark have been very prolific. Another common fault is backlash in the dial. This, of course, results in a curve more resembling a damped wave train than a straight line. Wavemeters are also a very fruitful source of trouble. Those who are about to construct a wavemeter would be well advised to use as large a variable condenser as possible in conjunction with the minimum number of inductances. There is a lighter side to the calibration department, however, as amongst other things which have been received were a thermo-ammeter described as a "milliammeter believed to be too fast," and a heap of powdered glass to be calibrated as a hydrometer. Readers who utilise the calibration service would not only benefit themselves, but assist us materially if they would make sure that their apparatus is in suitable condition and worthy of calibration before despatch.

Directive Radio Telegraphy and Telephony.

BY R. L. SMITH-ROSE, Ph.D., M.Sc., D.I.C., A.M.I.E.E.

III.—THE CONSTRUCTION AND USE OF A PORTABLE DIRECTION FINDER.

(*Continued from page* 257.)

During the last few years there has been considerable development in directional work, and there are obviously many applications of directional transmission and reception. We give below a general summary of modern methods and practice.

THE simple form of frame coil is now well known among experimenters as an alternative to the open aerial for reception purposes. It is seldom, however, that the directive properties of the coil are utilised, except possibly to eliminate or reduce interference. With a direction-finding receiver, however, many interesting experiments may be carried out, which will be very instructive both on the practical and theoretical sides of radio communication and the general principles of the propagation of electro-magnetic waves. Some precautions have to be adopted in the design, construction, and operation of a set in order that accurate readings of direction may be obtained. In the present article it is proposed to describe, in sufficient detail to enable construction to be carried out, a direction finder of the single-frame type, which combines accuracy of observation and ease of operation with complete portability of the whole instrument.

(a) Dimensions of Coil Frame and Stand.

In order that observations may be carried out at appreciable ranges of transmission, it is essential that stations of moderately high output power be used, which necessitates working on wave-lengths certainly not lower than 1,000 metres. Besides obtaining the advantage of the existence of stations of superior power on these longer waves, there is added that of longer and more regular transmissions. On the shorter waves, such as 600 metres, ordinary reception indicates that the transmissions of any given ship or shore station are very erratic in their frequency, and also usually of comparatively short duration—less than one minute—making reliable D.F. observations extremely difficult. The set about to be described is, therefore, given the convenient range of wave-lengths of from 1,000 to 10,000 metres, although it is a comparatively simple matter to extend this range in either direction.

The general appearance of the D.F. set is seen from the drawing in Fig. 1 and the photographs Figs. 2 and 3.

To cover the above range of wave-lengths two frame coils are used, each capable of being mounted on a rotating platform. For the larger coil a skeleton wooden frame is constructed of size 4 ft. square by 8 ins. deep. It is very simply made of 1″ square rods with brace pieces at the corners to give rigidity, as shown in Fig. 4. The 1″ square wooden strips forming the corners should be of hard teak and well-soaked in paraffin wax to provide adequate insulation for the winding, which is spaced by slots in the wood at $\frac{1}{4}$″ apart. Alternatively combs of ebonite or micanite may be provided, if desired. The frame is then wound with 34 turns of No. 20 S.W.G. silk-covered copper wire. Bare wire may be used for the coil, but is not recommended on account of the possibility of contact between adjacent turns should the wire become slack after it is wound. The "area-turns" of this coil equal 544 square-foot-turns, and its effective inductance is about 3 millihenries.

The smaller coil is of similar construction, but 2 ft. 6 ins. square, and wound with 25 turns at $\frac{1}{8}$″ spacing. The "area-turns" of the coil equal 156 square foot-turns, and the effective inductance is nearly 1.2 millihenries.

The tuning condensers for the set are mounted on an ebonite panel, which fits on the lower side of either coil frame. The panel

contains one variable air condenser of maximum capacity 0·0011 microfarad, with fixed mica condensers of capacity 0·001, 0·002, 0·004, and 0·008 microfarad. Switches are provided for connecting the fixed units in parallel with the variable condenser, so as to obtain a continuous variation of capacity up to 0·016 microfarad. This range is amply sufficient to tune the small coil over the wave-lengths from one to six kilometres, and the large coil from two to ten kilometres.

The wooden platform upon which the coils are mounted by simple bolts and wing nuts is carried upon a hollow brass spindle which passes through the top of a large wooden box, being supported on a steel pivot at the bottom of the box, as shown in the sectional drawing in Fig. 5.

The box indicated is constructed of ½" wood, and is of external dimensions 23" by 18" by 15" high, although the actual size may need to be varied to suit the amplifier and batteries in use. As shown in Figs. 1

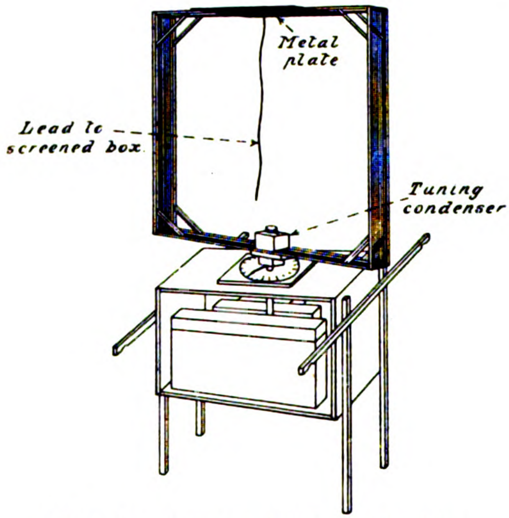


Fig. 1—General arrangement of the direction finder.

and 5, the box is mounted on legs, with its lower side about 14" above the ground, and it is also provided with a pair of carrying handles (see photograph Fig. 3). The outside of the box is entirely covered with tinned iron sheet of about 30 mils. thickness, and the open side of the box is provided with a tinned-iron lid, which is a good tight fit over the box, and provides an overlap of at least two inches. This lid is provided with handles to enable it to be removed, and also two circular holes through which the amplifier controls may be manipulated. The box serves as a shielded container for the amplifier, its associated batteries, and all connecting leads.

If the set is to be used much for outdoor work, it is recommended that the metal shield be protected with paint or enamel. Care should be taken, however, not to cover the portions of either the box or lid where these overlap, for good conductivity is required across this overlap joint, and the metal should be kept clean and bright.

(b) Apparatus and Circuit Arrangements.

The actual type of amplifier employed in the set is immaterial so long as it gives good reception for all wave-lengths from 1·0 to 10·0 km. The point to be borne in mind is that direction observations are made on a minimum or zero signal, and it is the rate of change of the signal strength near the minimum that determines the accuracy of the observation.

To give an adequate receiving range on the frame coil it is preferable to have at least three stages of radio frequency amplification. Following the detecting valve, there should be a choice of one or two stages of audio-frequency amplification. These will be found to considerably improve the accuracy to which the bearings can be observed, although the amplification should not be strained to the point of introducing valve noises.

Three low-frequency stages may be employed in favourable circumstances, but it is seldom that this arrangement can be maintained quiet while giving efficient amplification, and it is only by preserving a background of absolute silence that accuracy of bearings can be obtained.

If still greater sensitivity is desired more radio-frequency stages may be added, but it will be necessary to have an easily adjustable control to maintain the series stable. A potentiometer across the filament battery, by means of which the grids of all the high-frequency valves may be given a positive potential forms a convenient control. With such an arrangement it is usually prohibitive to employ any intentional reaction ; for if good bearings are to be obtained self-oscillation of the set must be entirely avoided. With careful design and construction, six high-

frequency valves, followed by a detector and two low-frequency valves, may be handled successfully, but this represents about the upper limit of amplification for D.F. purposes.

For such a number of valves the filament battery should be of adequate capacity, but since the set is to be portable, the size and weight of the battery must be considered. In the set illustrated ordinary " R " type valves were employed with a 6-volt 50-ampere-hour accumulator battery, but this could, of course, be reduced if dull-emitter valves are employed. The high-tension battery is a compact unit, preferably built up of small separate dry cells. The general arrangement of the amplifier and batteries inside the box is shown in the drawings in Figs. 1 and 5. These are all carefully insulated on paraffin blocks or porcelain legs from both the box and the brass spindle, supporting the coil. The batteries are placed behind the amplifier, and the latter is arranged so that its control handles may be manipulated through the hole in the metal cover closing the front of the box.

In wiring up the set, the ends of the D.F. coil are arranged to be at the centre of the lower side, where they are connected directly to the terminals of the condenser panel (Fig. 6). From the condenser terminals, the leads pass down the hollow spindle into the apparatus box, where they are brought out through a hole in the side of the spindle to the amplifier terminals. A sufficient length of the flexible leads should be allowed at this point to permit of the rotation of the frame for at least one turn in either direction. If it is desired to improve the selectivity of the whole receiver a loose-coupling arrangement may be employed, using honeycomb coils and a two-coil plug-in holder mounted inside the screened box. The leads passing down the spindle would then be connected to one coil, forming a primary coupling coil in parallel with the main frame and tuned by a parallel variable condenser. The secondary coil is connected to a variable condenser, also mounted inside the box, and the amplifier then connected across this secondary condenser.

Although the spindle actually makes metallic contact through the pivot with the screen cover of the box, it is advisable to

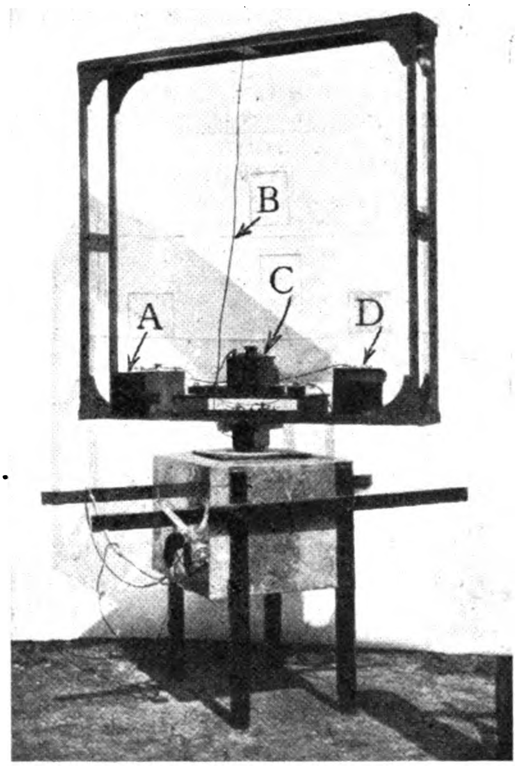


Fig. 2—View of portable direction finder showing A, oscillator; B, lead from capacity plate to box; C, tuning condenser panel; D, oscillator battery.

make a more reliable connection by means of a flexible lead soldered to both spindle and box.

A brass pointer is also sweated or clamped on to the spindle of suitable dimensions to rotate over a graduated cardboard scale one foot in diameter mounted on wood on the top side of the box (see Fig. 5). This scale should be accurately graduated from 0° to 360°.

For the taking of bearings upon C.W. stations it is necessary to employ a suitable form of local oscillation generator. Special precautions are, however, necessary in the use of this, for if any stray field from the oscillator links the D.F. coil, the resulting induced e.m.f. in the coil will vary as the coil is rotated, and at some point will pass through zero, or at least a minimum. Now the signal heard in the telephones is the beat note produced by interference between the

incoming and local oscillations. If either of these varies in amplitude as the coil is rotated the resulting telephone signal will vary in intensity.

It will be evident, therefore, that the observed reading on the coil in the position of minimum signal may be a false bearing produced by the variation in the linkage by the coil of the stray field from the local oscillator. It is often found, for example, that a set operated in this manner shows four minima in a rotation of the coil through 360°, two of these being genuine minima of bearing and the other two being false minima due to the oscillator.

The most satisfactory method of avoiding this trouble is to screen the oscillator in such a thorough manner that the stray field acting on the D.F. coil is reduced to a negligible quantity. Very elaborate precautions are necessary to attain this end, as will be described in a later article. A simpler alternative, which may be employed in many elementary experiments in direction finding, is to mount the oscillator, with its associated batteries, within the frame coil in the manner shown in the photograph in Fig. 2. By this means the coupling between the oscillator and the receiving frame is fixed, and any variation in the local oscillating e.m.f. is thus avoided. The chief disadvantage of this arrangement is that the strength of the local induced oscillation is not under control, and it is difficult to run the average type of valve oscillator at a low enough output to permit of the optimum signal strength being obtained on the receiver.

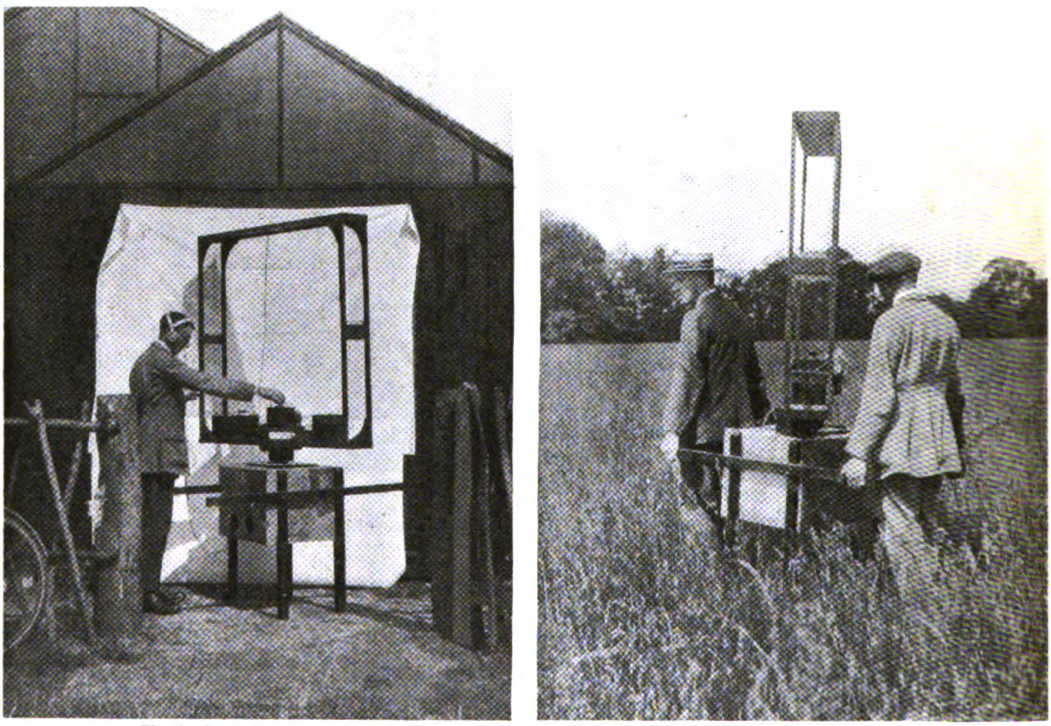


Fig. 3—Portable direction finder in use on the left and showing method of carrying on the right.

(c) Setting up and Operation of the Direction Finder.

In setting-up the receiver for the taking of bearings the set should be stood on a level surface so that the axis of rotation of the coil is as nearly vertical as possible. It is usually most convenient to have the coil set so that the pointer reads directly on the scale in degrees from the true geographical North, and for this orientation of the coil a good type

of prismatic compass is required. The coil is first turned so that the pointer indicates 90° on the scale, and then, standing at a distance of ten or twelve feet from the set, a sight is taken with the prismatic compass along one face of the frame coil, *i.e.*, in a direction parallel to the horizontal sides. It will be found that the edges of two opposite vertical sides of the framework can be brought into coincidence with the hair-line of the compass quite accurately. If the coil is set correctly the compass reading in this position should be equal to the value of the magnetic deviation at the place in question, plus or minus any correction for which the compass has been previously calibrated. The magnetic deviation is the angle between the magnetic and geographical meridians, and varies over Great Britain from about 14° in the South-East of England to 19° in the North-West of Ireland, the deviation being West of true North.

If the correct reading is not obtained in the above operation the coil stand should be gradually adjusted in the appropriate direction until the correct position has been found. The setting of the coil in this manner will result in the scale reading of 90° being obtained when the plane of the coil is in the geographical meridian, *i.e.*, pointing true North. Now the coil in this position will give a minimum or zero of signal strength for waves arriving at right angles to it, *i.e.*, from East or West (90° or 270°). When the D.F. coil is thus set in the above manner, and turned to the minimum position, the scale reading will indicate the true wireless bearing line for the signals being received without any further calculation. For additional accuracy in the above setting the coil can be rotated to a scale reading of 270°, and the compass observation repeated, sighting on the opposite side of the wooden framework.

The set being ready for use, the amplifier is switched on, and the condensers adjusted to tune in the required signals. If continuous waves are being received the oscillator must also be adjusted to give a suitable beat note. The conditions required for accurate bearing observations are good strong signals, as free as possible from any interference. In few cases can the signals be too strong, for it is to be remembered that near the minimum the signals are reduced to a small fraction of their maximum strength, and interfering signals, which would not affect reception in the maximum position, may become relatively strong at the minimum and seriously decrease the accuracy of observation. The interfering signals will, of course, have a minimum strength for a certain position of the coil, but in general they will come from a different direction to that of the required signals.

With the apparatus correctly adjusted, the lid of the screened box should be in position before a bearing is observed. The coil is then rotated to the position of minimum signal strength, and swung through a small angle to determine the scale readings at which an increase in the strength of signals in the telephones is just detectable on either side of the true minimum. The mean of the

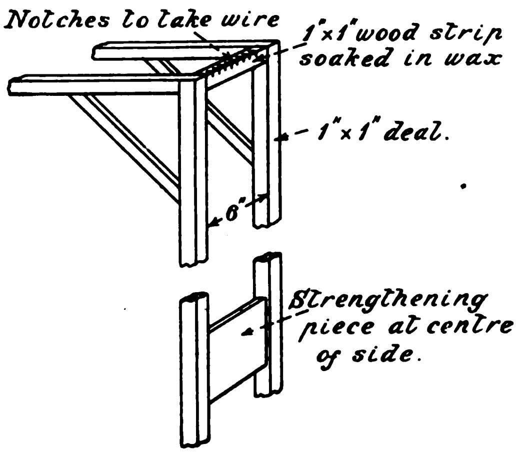


Fig. 4—Details of coil construction.

two readings so obtained is the observed bearing in this position, and half the swing is the "accuracy" of the observation.

To complete the determination the coil should be rotated through 180° and the above observation repeated to obtain a "reciprocal" bearing, *i.e.*, 180° away from the "direct" bearing of the transmitting station under observation. As these two will not usually be exactly 180° apart, the direct and reciprocal readings are added together, 180° subtracted, and the result divided by two to deduce the mean observed bearing.

(d) Method of Improving the Accuracy of Readings.

Probably the first desirable point in the operation of such a direction finder is to

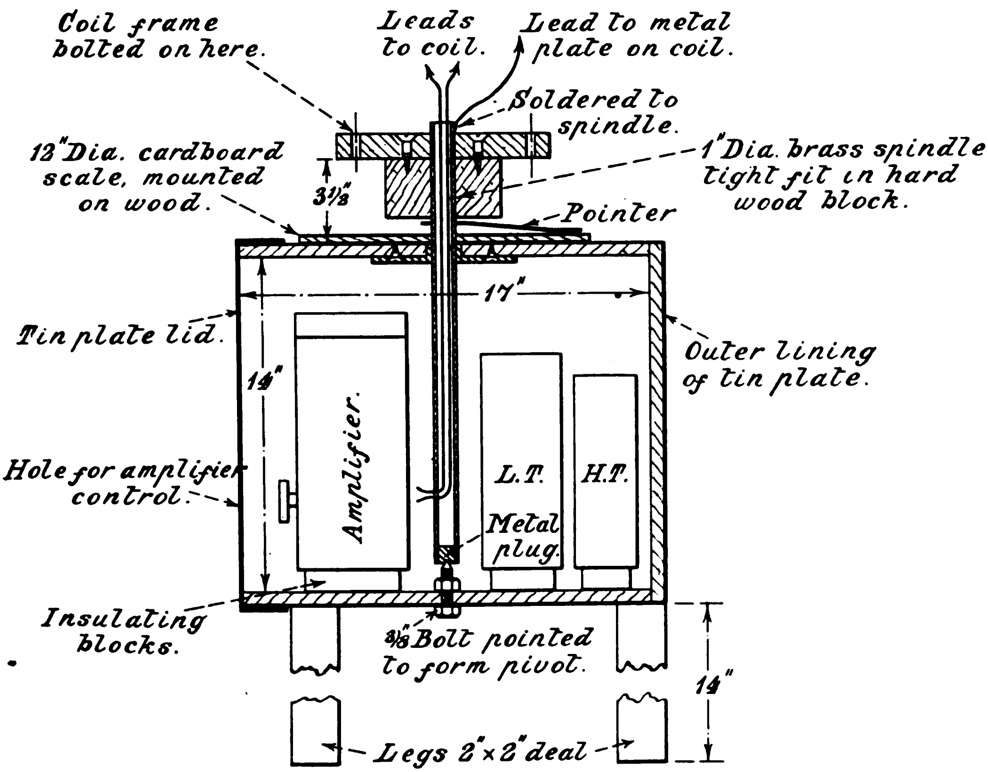


Fig. 5—Showing arrangement and dimensions of the case containing amplifier and batteries.

improve the sharpness of the minimum, *i.e.*, to reduce the angle of swing by which the bearing is determined. The fact that the minimum is not already sharp is due to the coil acting as an antenna with capacity connection to earth, as already explained.* The explanation there given suggests that if the capacity to earth of the input terminals of the amplifier can be equalised, this antenna effect of the coil, although still acting, will not give rise to any signals passed through the amplifier to the telephones. This compensation of the antenna effect can be carried out by the connection of a small variable condenser between the grid of the first valve and earth. The lead to earth should be as short as possible, passing directly below the box. For portable work a suitable "earth-pin" may be used, pushed into the ground near one leg of the set, but an excellent alternative is found in the use of a large plate of copper placed flat on the ground, and upon which is stood the whole set. In either case, the metal screening box should be connected to this "earthy" terminal. In the taking of a bearing, the coil is swung slowly about the minimum position, while the compensating condenser is adjusted until the setting to give the sharpest minimum or zero has been found. In many cases it will be found that this method will enable the observed bearing to be located with an angle of swing as small as 0.1°. With such sensitivity it will usually be found that a slight movement of the operator will alter the necessary adjustments, since he is contributory to the antenna effect *via* the telephone receivers. In taking the reciprocal bearing a fresh adjustment of the compensating condenser will in general be necessary, and the setting also varies for the observations made on other signals and wave-lengths.

Another method of improving the accuracy

* See EXPERIMENTAL WIRELESS, January, 1924, Vol. I, p. 194.

of the bearing observation is that which was actually adopted in the set described above. A "capacity" plate of tinfoil or copper gauze is mounted on the top horizontal part of the coil frame immediately underneath the winding, as shown in Figs. 1 and 6. A lead from this plate is brought straight down across the centre of the frame, and connected to the metal screen of the apparatus box, which itself need not be earthed. This arrangement will be found to greatly decrease the antenna effect of the coil, and result in a considerable sharpening of the signal minima, although these will not be so sharp as those obtainable with the compensating condenser. By such means, however, bearings can be observed to an accuracy of 1° or 2°, which is as close as many practical applications, and certain other defects inherent in direction finders, warrants at the present time. This last method, moreover, has the great advantage of not requiring any adjustment whatever in observing on signals on different wave-lengths.

Should the above methods not result in the production of sufficiently sharp minima for observation purposes, under favourable conditions, an undue amount of "direct pick-up" on the amplifier and connecting leads should be suspected. A thorough inspection of all the parts of the apparatus forming the screen should be made, particularly ascertaining that all unnecessary holes and cracks are eliminated, and that all joints are thoroughly sweated, and preferably covered with a thin strip of tinplate.

(c) Observations and Experiments to be carried out.

One of the most important experiments to be carried out with such a direction finder when constructed and working is to ascertain the reliability of it as a portable direction finder. To do this an open site should be chosen as the field of operations, this site being quite free of trees, overhead wires, streams or river, and buildings for a radius of at least two hundred yards. The apparatus should then be erected in the manner described and observations of bearings taken on transmissions from the nearest station within the wave-length range of the instrument. The observations should be repeated at five-minute intervals for about half an hour. If the transmitting station is reasonably near, and the observations are made near mid-day, the bearings so obtained should agree within one or two degrees, and by taking the mean of the set of readings a fairly accurate value of the observed bearing is obtained. The whole apparatus is now transported a distance of fifty or one hundred yards and the operations repeated. Except when the transmitter is within five miles such a change in position makes no appreciable change in the true bearing, and the mean observed bearing, therefore, should be the same as before. If this is not the case, it means either that the setting of the coil by

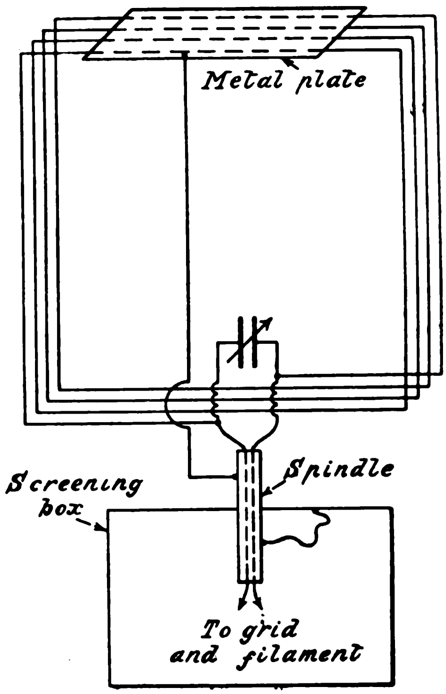


Fig. 6—Connections of the frame to amplifier.

compass is not accurate or that an error of observation is involved. With continued repetition of these operations, it will be found that skill is acquired in the taking of accurate bearings, and that the observations can be repeated to within 2° or 3°, but not closer than this.

Having established the reliability of the set for the observation of bearings, it may then be used for the determination of the nature and magnitude of the errors introduced by various local conditions, such as

trees, buildings, telegraph wires, railway lines, and tuned coils and aerials. It was, in fact, with such a portable set that the majority of the results described in Part II* of this article were obtained. There is still much room for useful experimental work in this direction, particularly in the investigation of the effect of change in wave-length on the errors introduced by any one or more fixed local disturbances.

Probably the most attractive field for investigation with this type of direction finder, however, is that of the study of variations in bearings. With the apparatus set up and correctly oriented in some fairly permanent location, two or three transmitting stations within the working range of the instrument should be selected for observation purposes. Readings of the apparent bearings of these stations should then be taken in rotation, the cycle of observations being repeated at intervals of five or ten minutes, Having once determined the apparent bearing of each received signal, its value should be immediately noted on an observation form. upon which should also be recorded the nature of the signal minimum as judged by the angle of swing, and also the prevailing conditions of observation, such as interference by signals and atmospherics, etc. If such a series of systematic observations is made for a period of one or two hours at a time, and repeated at regular intervals, or from day to day, several interesting facts will be observed, the salient points of which have already been described in Part II* above. Although it is not always the case, it will frequently be found that when the observed bearings are seriously different from their true value, the minima are also very flat, making an accurate observation difficult to obtain. In some cases it will be found that there is no detectable change in the intensity of the signal as the coil is rotated through 360°. While most of these effects can be accounted for in a qualitative manner on the existing theories of electro-magnetic wave propagation, there is still a great scarcity of accurate quantitative data on the subject. A final suggestion which may be given to the experimenter who is sufficiently interested in this matter to carry out serious investigations, is that the observation of variations of bearings might be combined with simultaneous observations of the "fading" of the signals received. Some simple method of measuring the strength of the signals should be adopted, the signals being received either on a separate aerial or on the direction finder with the frame coil placed in the maximum position, *i.e.*, with its plane parallel to the direction of the transmitter.

* See EXPERIMENTAL WIRELESS, February, 1924.

The Self Capacity of Coils.

ITS EXACT EFFECT AND WHERE IT MAY BE IGNORED.

By J. H. REYNER, A.C.G.I., B.Sc., D.I.C.

THE self capacity of a coil, as is well known, is the resultant effect of the capacity between the various turns of wire in the coil, and it is generally considered highly undesirable and to be avoided at all costs. Consequently there are on the market numerous forms of low capacity coil which have been described from time to time, and are familiar to every radio enthusiast.

Now, although the reduction of self capacity has become almost a fetish, it is, in many cases, of secondary importance only. It is proposed in this article to indicate the exact effect of self capacity, so enabling the experimenter to decide what precautions should be taken.

Values of Self Capacity.

The value of the self capacity is in most cases very low. The problem has been investigated by many eminent scientists, notably Professor Howe (*Journal I.E.E.*, December, 1921), and Professor Morecroft (*Proc. I.R.E.*,

August, 1922) and the results in some particulars are by no means consistent.

It appears that for single-layer coils, the self capacity is about ·6 r (where r is the radius in cms.), irrespective of the length and number of turns. For multi-layer coils the value is somewhat higher, and may have a value of up to 1·5 r. In any case, the self capacity is of the order of from 5 to 15 micro-microfarads, which is smaller than the stray

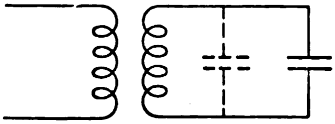


Fig. 1.—The E.M.F. is introduced in the coil itself.

capacities in the circuit. With an ordinary valve and four-pin socket the capacity between grid and filament is of the order of 20 micro-microfarads, in addition to which there are the capacities of the leads, switches, etc., so that in general the self capacity of the coil is of secondary importance.

Effects of Self Capacity.

Turning now to the effects of self capacity, the first consideration is the position of the coil in the circuit. It will readily be understood that there are two possible conditions :

(*a*) When the e.m.f. in the circuit is introduced in the coil itself ;

(*b*) When the e.m.f. is introduced in series with the coil.

Fig. 1 shows the condition (*a*). It will be observed that in this case the only effect of the self capacity is to increase the tuning capacity across the coil.

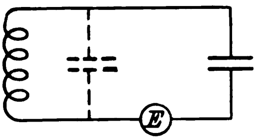


Fig. 2.—The E.M.F. is introduced in series.

Now the energy in the circuit is usually limited, being given by $W=\frac{1}{2}CV^2=\frac{1}{2}LI^2$. Where the voltage is required to be a maximum, as in receiving and detecting circuits, the capacity must be made small and the inductance large.

The effect of self capacity in the coil will be to increase the minimum of tuning condenser, and so to reduce the range. Whether this is permissible or not depends on circumstances, but in many cases it does not constitute a serious disadvantage.

Where a large current is required, on the other hand, C is made large, and in this case the self capacity, neglecting losses, has no detrimental effect.

The second condition is illustrated in Fig 2, the E.M.F. being in series with the coil. Now the apparent resistance to an external E.M.F. of an inductance and condenser in parallel varies with the frequency, and increases enormously as the resonant frequency is approached.

The actual value of the apparent resistance R is given by

$$R=\frac{R_0}{(1-w^2LC_0^2)}$$

where L = inductance
C_0 = self capacity
R_0 = true resistance of the coil.

Fig. 3 gives a curve showing the ratio of R/R_0 in terms of the ratio λ/λ_0 being the wavelength used, and λ_0 the natural

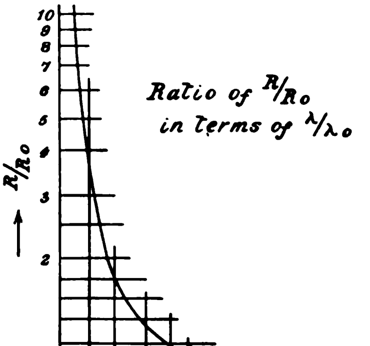


Fig. 3.—Ratio of resistances expressed as ratio of wave-lengths.

wave-length of the coil (*i.e.*, the wave-length to which the coil tunes without any added capacity).

It will be seen that, even at a wave-length five times the natural, the increase of resistance is still appreciable and it is in a case like this that a low capacity coil may be used with advantage. Circuits of this type are frequently met in practice, Fig. 4 being a case in point. Here L would be made high, and C small to obtain the maximum voltage on the detector. Unless a low capacity coil is employed, the natural wave-length might only be one-third or one-fourth of the working

wave-length, in which case the extra resistance effect would more than neutralise the gain in signal strength obtained by using a small tuning condenser. Such a circuit is often employed for extending the wave-length of a given set.

Tapped Coils.

Self capacity is responsible also for the dead end effect noticeable when tapped inductances are employed. E.M.F. is induced in the overhanging portion, and the circuit is closed by the self capacity as in Fig. 5. Moreover, as there is an auto-transformer effect, the voltage across the coil may be several times as large as that across the tapped part. For this reason a coil should never be tapped more than half-way down.

Energy is, of course, absorbed from the main oscillating circuit, so causing the

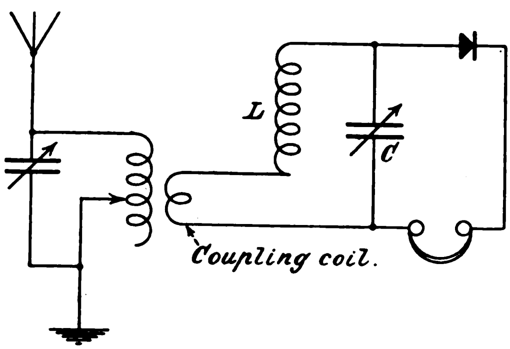
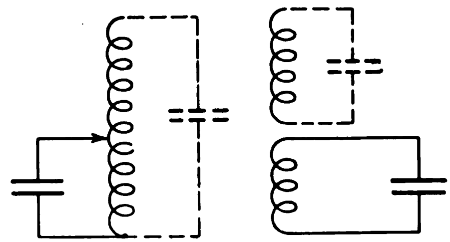


Fig. 4.—L should be high and C small to give maximum voltage on the detector.

apparent resistance to increase. The effect is particularly severe if the working wave-length is near the natural wave-length of the whole coil (including the overhanging turns). In this case the circuit will be found to have two resonant frequencies, and may change from one to the other with a jump. Where the overhanging portion is large it is better to short circuit the turns rather than leave them open, as less energy is absorbed and the double frequency effect is obviated.

The trouble may be avoided to a large extent by completely isolating the unused turns, as in Fig. 6. The only danger here is if the second coil is anywhere near resonance with the main coil, but this is not such a likely contingency. Trouble may arise, however, in "universal" receivers having all coils from 300-30,000 metres in the same set. Marked "flat spots" are apt to be found when the coil in use comes into tune with some higher valued coil, which is resonating through its self capacity.



Figs. 5 and 6.—In Fig. 5 self-capacity closes the overhanging portion, and this effect can be reduced by isolation as shown in Fig. 6.

Losses.

An aspect of the question which is not always considered is that of the losses due to self capacity. The electric strain passes through the former of the coil and the insulation of the wire. In particular, cheap paper formers, imperfectly dried, are liable to cause heavy losses. End connections are another feature which deserve attention; the ends of the coil are often brought to plugs in a socket of insulating compound. If this is of poor quality an increase of 10 per cent. in the effective resistance may result.

In general, end connections deserve attention. A construction such as is shown in Fig. 7 will more than double the self capacity.

Variometers and loose couplers in particular should be wound on high grade formers to

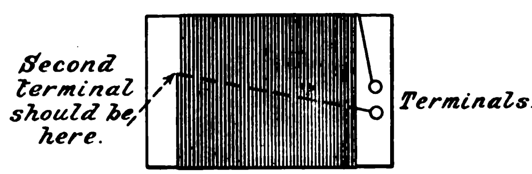


Fig. 7.—The arrangement of the leads shown above will more than double the self-capacity of a tuning coil.

avoid loss, since the capacity between rotor and stator has the stator former for a dielectric. From this point of view the types of variometer employing internally wound stators are preferable.

High-Frequency Resistance.

Many experimenters seem to imagine that the determination of high frequency resistance necessitates the use of complicated apparatus. However, by the simple methods described below fairly accurate results may be obtained.

IN the course of their many different experiments, both in transmitting and in receiving, most genuine experimenters have probably asked themselves the question, "Now I wonder what the effective resistance of that coil really is?" They know that by using our old friend Wheatstone's bridge, or even by simply referring to wire tables, that they can easily find out, at any rate near enough, what the resistance of their coil is to direct current, but it is, or should be, a well-known fact that that does not help us much when we are working at a frequency of, shall we say, 10^6 ∽.

Now, the average experimenter imagines—and, I think, quite rightly imagines—that it is a difficult laboratory experiment to determine accurately the resistance of a coil of wire at such a high frequency as a million. But at the same time it would be extremely helpful to the experimenter if he could simply determine the approximate resistance of his coil and so find out if its resistance was sufficient to damp his circuit seriously. It is, therefore, the object of this article to give a brief outline of some of the methods used to determine high-frequency resistance, with a few practical details where the method is suited to our purpose. Where the method obviously requires expensive instruments and elaborate apparatus there is obviously no need to give "full instructions."

Method I.—Calorimetric.

Perhaps the most obvious effect of a current flowing in a coil of wire, and one that is quite independent of frequency—apart, of course, from resistance variation—is that the current heats up the wire.

Now, if we have a coil of wire of H.F. resistance R_x, the unknown which we wish to determine, we know that, with a current I flowing in it, the power P lost in heat is I^2R_x. If, then, the coil is placed in an oil bath, and the temperature rise for a given period noted with the current I flowing, P may be determined, and if I is accurately known at the frequency we may easily calculate R_x.

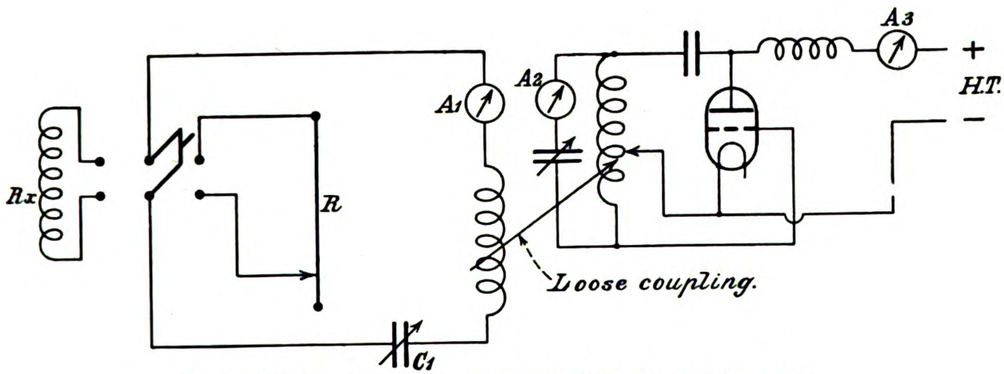


Fig. 1.—Illustrating the arrangement of the circuit for the substitution method.

An improvement on this method, and one more suitable to our purpose, is to determine P electrically; that is to say, obtain a given rise of temperature of our oil bath both with H.F. and D.C. current, and then equate the two losses. If this is done, and R_1 and I_1 denote the D.C. values of R_x and I, then we may say—

$$R_x = \frac{R_0 I^2}{I^2}$$

If a suitable calorimeter is available, and the coil is not too large, this method might easily be used by the experimenter. With a little ingenuity the expansion of the air in a closed vessel containing the coil may be used to indicate the watts dissipated, this being simpler than using a thermometer and an oil tank. The chief errors likely to

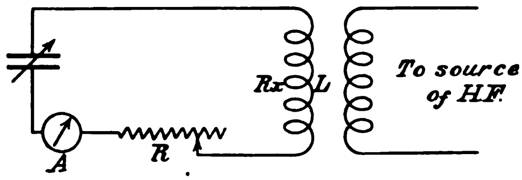


Fig. 2.—Circuit for Method III.

arise in this method are those due to unaccounted losses of heat and also that assumption that all the energy is lost in heat. At high frequencies, with large coils, quite an appreciable error might be introduced, due to energy being radiated.

Method II.—Substitution.

In this method the coil whose resistance is to be measured is placed in some circuit and the current through it measured at the required frequency. Then, without altering the conditions of the circuit, the coil is removed and a standard known resistance inserted and adjusted to give the same current reading. Then, obviously, the resistance of the coil equals the resistance of the standard inserted.

This method has really been described already by the author in his paper on "Antenna Constants."

This method is by far the simplest *on paper*, but the practice is a very different story. The chief difficulty is to keep the conditions in the circuit in which the coil is inserted *exactly* the same in both cases, and also to obtain a standard resistance which is constant at all frequencies and continuously variable.

If, however, care is taken in the construction of a variable straight-wire resistance, results of a fair accuracy may be obtained if the resistance is not too high.

In Fig. 1 is given a suggested circuit for this method.

In order to test if the conditions are the same in both cases, the change-over switch is moved from one side, and if the circuit is kept in resonance by the variable condenser C no change should take place in either A_2 or A_3 when R is substituted for R_x.

The frequency may, of course, be measured by means of a wave-meter loosely coupled to the "driver" circuit. The resistance R may be constructed by stretching a long, thin Eureka wire along a board and calibrating it previously either from tables or by means of a Post Office box.

Method III.

Another method which may be really included under the last head is the Resistance Variation method. In this case a circuit such as that shown in Fig. 2 is used. In this case the unknown and the standard are both connected in the circuit. Two readings of the current are obtained in A, firstly with R at zero value I, and then with a resistance R_1 inserted, giving a value I_1.

Then we have—

$$I = \frac{E}{R_x}$$

$$I_1 = \frac{E}{R_x + R_1}$$

$$\text{hence } R_x = \frac{R_1}{\frac{I}{I_1} - I}$$

The disadvantage of this method is that an accurate H.F. ammeter is necessary, but a "Moullin" H.F. ammeter (see later) might well be used here.

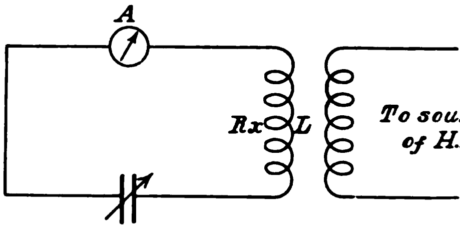


Fig. 3.—The arrangement for Method IV.

Method IV.

In this method no standard resistance is used, but the reactance of the circuit is altered and two readings obtained (Fig. 3).

An observation of A is made with the circuit in resonance. We then have—

$$I_r^2 = \frac{E^2}{R^2}$$

A second reading is then obtained with

the circuit when the circuit is slightly out of resonance $I_1{}^2$, in which case—

$$I_1{}^2=\frac{E^2}{R^2+X_1{}^2}$$

$$\text{and hence } R=X_1\sqrt{\frac{I_1{}^2}{I_r{}^2-I_1{}^2}}$$

The value of X_1 may obviously be calculated from the values of C and L, and hence R is obtained.

This method is not easy to manipulate, involving, as it does, an accurate knowledge of C and L, also a very constant value for E, and hence is not really suited to our purpose.

Method V.

This method, due to Prof. E. Mallet, M.Sc., is really also a reactance variation method, but is one which the author has personally used with a certain amount of success. If we consider two coils, as in Fig. 4, let us suppose that L_1 carries a current I_1 producing an E.M.F. E_1 across the coil; and let us suppose L_2 is coupled to L_1, but not in resonance with it, such that the mutual inductance between the two coils is M'. Then there will be a P.D. E_2' across L_2, and, neglecting the self-capacity of L_2, the E.M.F. induced in L_2 will equal the P.D. E_2'. Now, by connecting a crystal detector and galvo. across L_2, a reading on the galvo. may be obtained proportional to E_2'.

Now we may say—

$$E_2{}'=\omega M^1 I_1$$

In case (*b*) the circuit L_2 is brought into resonance with L_1, the frequency being kept constant. Then the P.D. across the coil will now be E_c, and will not be equal to the E.M.F. induced E_2''. If the reading on the galvo. is kept constant in both cases we may say—

$$E_c=E_2{}^1$$

$$E_c=\frac{I_2}{\omega C}$$

$$I_2=\frac{E_2''}{R}, \text{ when R is the vector of circuit } L_2\, C_2.$$

$$\text{Then } R=\frac{E_2''}{I_2}=\frac{\omega M'' I_1}{E c\,\omega C}=\frac{M'' I_1}{\omega M^1 I_1 C}$$

$$=\frac{M''}{M^1}\cdot\frac{1}{\omega C}$$

Hence we see that if we first calibrate the mutual between the coils L_1 and L_2 either by experiment or by calculation, if we know, as we may easily do, the value of C and W, the value of R may be easily calculated.

This method works extremely well provided the natural frequency of the coil L_2 is not approached. Obviously, if the frequency used is brought anywhere near to the natural of L_2 the self-capacity of the coil can no longer be neglected and the method fails. I had better, perhaps, mention, to save unnecessary argument, that this method is obviously only approximate, as the statements just made are not absolutely true, but with the above reservation they are good enough for ordinary work and give quite good results. In practice, the author checked readings obtained for a coil by this method by inserting a small non-

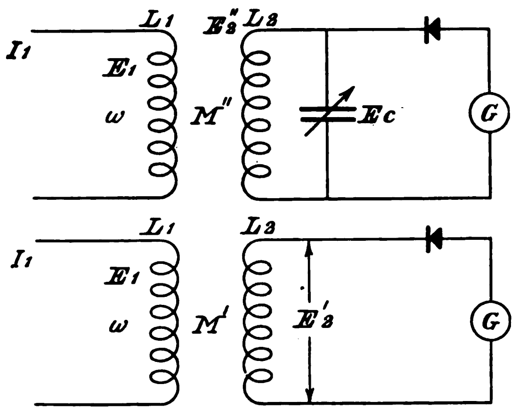


Fig. 4.—Illustrating the circuits used for Method V.

inductive resistance (3" No. 40 Eureka) and checking its resistance by subtraction.

The obvious disadvantage of this method is the necessity for a calibrated mutual inductance, but, as the reader has probably already gathered, in all these methods there is always a snag somewhere!

Method VI.—Potential Drop Method.

In this last method advantage is taken of that law which comes into almost everything electrical one can think of, namely, Ohm's law.

We know that in a D.C. circuit—

$$I=\frac{E}{R}$$

and that in an A.C. circuit—

$$I=\frac{E}{\sqrt{R_2{}^2+\omega^2L^2+\frac{1}{\omega^2C_2}}}$$

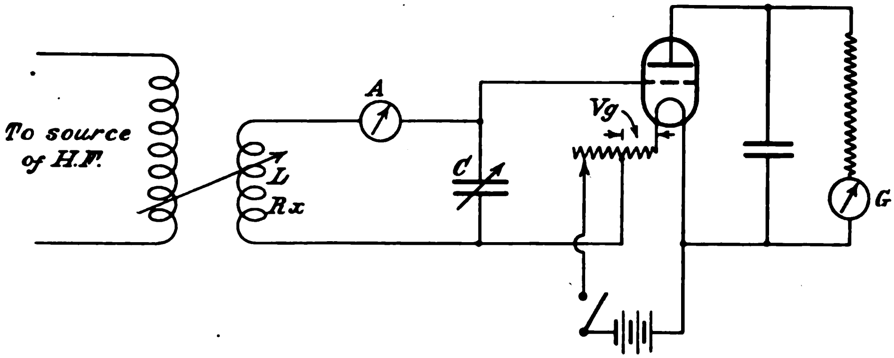


Fig. 5.—The resistance is here measured by the potential drop method by the apparatus shown above.

Now, if we wish to measure the resistance of a coil of wire of value R_x ohms and L henries, if we can pass a known current through it, and measure the P.D. across its ends, we can easily determine R.

It occurred to the author that the "Moullin"* H.F. voltmeter might very well be used for this purpose. In small coils we may neglect C, and hence the equation becomes—

$$I = \frac{E}{\sqrt{R^2 + \omega^2 L^2}}$$

Now, we may calculate L to a fair degree of accuracy from tables or else measure it on an inductance bridge; we may easily find ω by means of a wave-meter; hence, if we can determine E with sufficient accuracy we have a simple method of measuring R.

A suggested circuit is given in Fig. 5.

In this arrangement the valve grid is made about 1·6 volts negative to reduce the grid damping to a negligible amount. Advantage is then taken of the curvature of the grid-volts anode current curve of the valve.

The readings of the galvo. in the anode circuit of the valve may be obviously first calibrated on D.C., so that a direct reading of volts may be obtained. A current is then obtained in A of value I_1, and P.D. read off on G., V_1.

Then we have—

$$I_1 = \frac{V_1}{\sqrt{R^2 + \omega^2 L^2 + \frac{1}{\omega^2 C^2}}}$$

* See *Wireless World*, 1922, x, 1; also paper read before Inst. Elect. Engrs., December, 1922, by E. B. Moullin.

Now, if we bring the circuit L_2C into resonance with the frequency of the supply, we know that—

$$\omega L = \frac{1}{\omega C}$$

$$\text{hence } I_1 = \frac{V_1}{R}$$

$$\text{or } R = \frac{V_1}{I_1}$$

In this way we obtain a very simple method of obtaining the value of R. The only apparatus necessary is a H.F. ammeter, such as a hot wire ammeter—which, although notoriously inaccurate, may be calibrated against a standard, a receiving valve and a D.C. volt-meter for calibration purposes.

Perhaps the simplest method of arrangement would be to have a change-over switch so that a grid battery and voltmeter could be brought into action after each reading and the galvo. need not be actually calibrated in volts.

This method completes a very rough survey of the main methods of H.F. resistance. It is not proposed to deal in this paper with the measurement of condenser resistance.

It is left to the enthusiastic experimenter to decide which method he will use, but, on the whole, the author would recommend the last method as requiring very little apparatus, and which, with care, should give quite good results. Of the other methods perhaps the resistance substitution method is the next best, but, as has been mentioned before, great care must be exercised to keep the conditions constant throughout. In the case of the last method, if a reliable H.F. ammeter (if such a thing exists) is not

available, the same principle as that used in measuring the P.D. across the coil might also be used for measuring the current through. In this case a small known non-inductive resistance could be inserted and the drop across the ends of it measured with a second valve. This again could be calibrated on D.C. This last is only a suggestion, and has not been tested by the author.

In conclusion, the author would be very pleased to hear from anybody who obtains results from any of these methods, as the subject is an extremely interesting one, and more practical data is very necessary.

"Howling" in Resistance Amplifiers.

ITS CAUSE AND ELIMINATION.

By F. M. COLEBROOK, B.Sc., D.I.C., A.C.G.I.

Probably every experimenter, when building a capacity coupled amplifier, has been troubled by howling. The cause and method of elimination are discussed below.

FROM a theoretical point of view the resistance-capacity coupled amplifier (the usual arrangement of which is illustrated in Fig. 1) possesses many attractive features, the chief of which is the relative independence of frequency of the amplification it produces. This applies over the whole range of audible frequencies, and even at high frequencies this uniformity of performance can be maintained up to about 3,000 metres without much difficulty. For wave-lengths shorter than this there is, unless special precautions are taken, a very marked falling off in efficiency, attributable to inter-electrode and other stray capacities.

From a practical point of view, however, the resistance capacity arrangement has certain definite disadvantages. Some of these, as, for instance, the wasteful fall of potential in the anode resistances, and the comparatively low amplification per stage, are inherent and unavoidable, and must be written off against the advantages of the system. Another serious defect is the one which forms the subject of this paper, namely, the internal instability of the amplifier, the effect of which is to produce, at best, a loud rushing sound, and at worst, a harsh and particularly discordant howling noise in telephones connected to the output end. This troublesome tendency is particularly marked in cases where the input circuit is capable of oscillation at radio frequencies.

It had long seemed probable to the writer that this effect would, on investigation, be found to be associated with the unsymmetrical nature of the charging and discharging paths of the grid condensers. Referring to Fig. 1, it will be seen that if by any means the plate of the grid condenser, which is connected to the grid, acquires a charge which makes its potential positive with respect to the negative end of the filament, this charge can disappear by flowing as an electric current through two paths, one being the grid leak and the other the direct conduction between the grid and the filament (*i.e.*, a flow of electrons from the filament to the grid). If, on the other hand, this plate of the condenser becomes negatively charged with respect to the negative end of the filament only one path is available for its discharge, namely, the grid leak, since electrons will not pass from the grid to the filament.

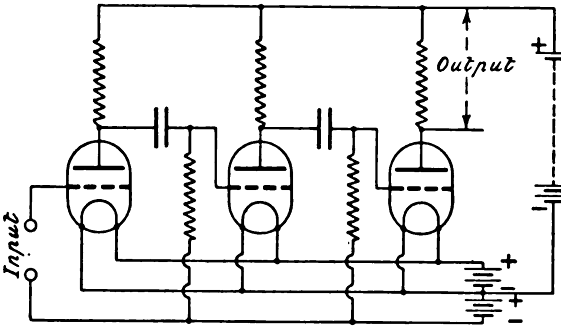
It was quite by chance that the writer hit upon a single-valve circuit which demonstrated that the low frequency howl of resistance amplifiers was definitely associated with this asymmetrical charge and discharge condition, and which indicated the means by which he has since succeeded in eliminating, or at least, very greatly reducing, this tendency.

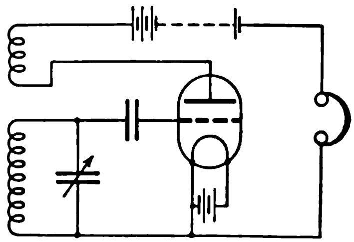
The circuit is illustrated in Fig. 2 and is seen to consist essentially of an oscillatory circuit connected through a condenser of

about ·0002 microfarads to the grid, there being in the anode circuit a reaction coil sufficiently closely coupled to the oscillatory circuit to cause and sustain oscillations in the latter when the grid condenser is short-circuited. In the case in which the effect to be described was first noticed the coils actually consisted of two equal windings of three turns each on an eighteen-inch square frame aerial, but the actual type of coil is non-essential, though the effect is more pronounced at short wave-lengths (300 to 1,000 metres). On listening with the telephones it will be found that for a considerable range of variation of the tuning condenser there can be heard a succession of loud clicks occurring at quite regular intervals of about a second or so. Towards either end of the tuning condenser range in which these clicks are heard their frequency increases very rapidly, and by careful adjustment of the tuning condenser it will be found possible to speed them up until the effect is that of a continuous growl, a noise very similar in character to the usual low frequency howl.

Now it can be shown that each of these clicks is associated with the sudden starting and stopping of high frequency oscillations in the oscillatory circuit. This fact can be demonstrated by means of an ordinary heterodyne wavemeter. Having adjusted the circuit to the condition in which clicks are occurring at a fairly slow rate, say, one or two per second, the heterodyne wavemeter is brought into the neighbourhood of the oscillatory circuit. It is then tuned to the frequency of the latter, when it will be found that the clicks change slightly in character. They occur at the same rate, but each click finishes with a sort of squeak, the pitch of which depends on the degree of closeness of the tuning of the wavemeter. This squeak is clearly the momentary heterodyne beat between the wavemeter oscillation and the sudden brief oscillation of the valve circuit.

The reason for this interrupted state of oscillation is not difficult to see. In its initial condition, the plate of the condenser, which is connected to the grid, takes up an equilibrium potential (about -2 volts), which is just sufficient to prevent the flow of any electrons from the filament to the grid. When the oscillatory circuit breaks into oscillation the grid connected condenser plate assumes a positive potential once in every cycle, with the result that more electrons are drawn to the grid. The only way of escape for these electrons is through the very high resistance path offered by the insulation of the condenser and through the insulating material of the valve-holder. The rate at which they can so escape will be very much slower than the rate at which they accumulate on the grid during the positive half-cycles of the oscillations. Consequently, as long as the oscillations persist the mean potential of the grid becomes more and more negative. Finally the grid becomes sufficiently negative to stop the oscillations. After this point is reached the grid will become less and less negative owing to the leaking away of the charge through the various insulation paths until once more a point is reached at which the oscillations will re-commence, a click in the telephones being produced by the





Figs. 1 and 2.—On the left is shown the normal arrangement of a resistance coupled amplifier, while on the right is a circuit illustrating the origin of howling.

consequent sudden change in the mean anode current flowing through them. This explanation is not invalidated by the fact that it involves something in the nature of an inertia effect, the oscillations persisting at a lower grid potential than is required to start them, for this is a fact of frequent occurrence in valve generation.

The frequency of the clicks clearly depends on two main factors. One of these is the effective negative resistance of the grid circuit—in other words, the force tending to set the grid circuit in oscillation. It is for this reason that the frequency of the clicks was found to depend on the setting of the tuning condenser. The other important factor is obviously the resistance of the leakage paths for the discharge of the grid condenser. Lowering the resistance of these paths will tend to increase the frequency of the clicks. This can be confirmed by inserting a grid leak of high value, say, five or six megohms, when it will be found that for certain settings of the condenser a howl of unmistakably the same character as that associated with the resistance capacity amplifier can be produced.

To relate this to the actual case of a resistance-capacity amplifier it is only necessary to remember that the input grid circuit of a properly designed amplifier of this type will nearly always have a negative effective resistance, even when there is no externally applied reaction. It appears that the stray capacities associated with the components of the amplifier are quite sufficient to produce a marked reactive effect. This is specially the case when the operator is wearing telephones connected in the output end. The conditions are, therefore, essentially the same as those obtaining in the experimental circuit described above, and the tendency to howling can reasonably be attributed to the same cause.

The remedy suggested by this analysis is the removal of the asymmetry in the charging and discharging paths of the grid condensers. This can be done by using grid leaks of sufficiently low resistance to ensure that there shall be no appreciable change of mean grid potential even if the input circuit does oscillate. This is preferable to preventing the oscillation of the grid circuit, as it is in nearly every case desirable that the input circuit shall have as low a resistance as possible, while in certain cases the oscillation of the input circuit may be essential for the purpose to which the amplifier is being applied.

The value chosen for the grid leaks should be the highest consistent with the requirement indicated above. Apart from any other consideration, the grid leak resistance should be as high as possible compared with the impedance of the grid condenser for the frequencies at which the amplifier is to operate. There is, however, another reason why this resistance should not be brought lower than is found necessary to maintain the grid potential at a constant value. This reason lies in the fact that whatever resistance is connected between the grid and filament of any given valve is virtually a shunt to the resistance inserted in the anode circuit of the valve which precedes it. The efficient operation of a resistance amplifier requires that the anode resistances shall have as high a value as is practicable compared with the internal (slope) resistance of the valve. For instance, assuming values 50,000 ohms and 10 for the internal resistance and the voltage factor of the valve, an inserted anode resistance of 100,000 ohms will give a theoretical voltage amplification of $\dfrac{10}{1+\dfrac{50{,}000}{100{,}000}}$, *i.e.*, 6·66 per stage of amplification. If, however, the grid leak of the following valve has a resistance of only 100,000 ohms the effective anode resistance will be reduced to 50,000 ohms (the two resistances of 100,000 ohms in parallel) and the theoretical amplification factor per stage will be reduced to $\dfrac{10}{1+\dfrac{50{,}000}{50{,}000}}$ *i.e.*, 5.

The writer has found in practice that a very suitable compromise is the use of grid leaks of about one quarter of a megohm. This arrangement affords a very great gain in silence and stability of operation, with no appreciable loss of sensitivity.

The Telephone Receiver and its Application to Wireless Circuits.

By ALEXANDER J. GAYES.

Almost invariably those engaged in experimental work relating to the reception of weak signals confine adjustments to the amplifier and rectifier circuits and simply employ a good pair of telephones In the following article the conditions giving maximum sensitivity are discussed and suitable arrangements of circuits are shown.

THE successful reception of wireless signals, either Morse, speech or music, depends to a large extent upon the accuracy and efficiency with which the undulating currents are finally converted into sound energy. In view of this, one would expect to find more attention devoted to the perfection of telephone receivers as applied to wireless apparatus than is usually given to this vital link in the chain of communication. The telephone engineer has, of course, made an exhaustive study of the receiver, and has produced an article which, from his point of view, may be open to very little improvement, and it is this receiver which, in the majority of cases, is used by the wireless expert after certain modifications in the way of windings. There are exceptions, as, for example, in the reed form of receiver, but the magnetic principle of this being similar to that of ordinary receivers, much of what follows will apply equally to the reed pattern receiver.

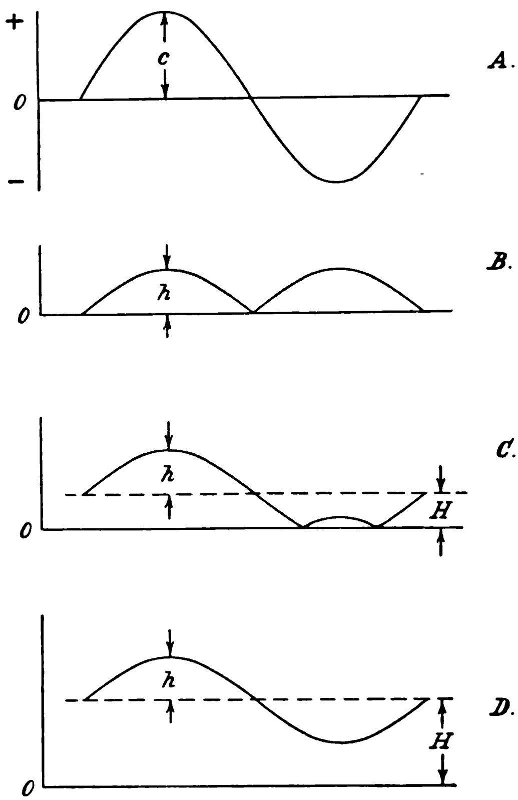


Fig. 1.—Illustrating the conditions obtaining in a telephone receiver.

It is proposed now to make a cursory study of the problems associated with the design of the receiver to find whether, in adapting the receiver to wireless circuits, full advantage is being taken of the points so carefully introduced by the designer. The first fact apparent to the observer is that receivers differ considerably in size. In the larger forms, generally referred to as loud speakers, receivers have secured their full share of attention from the experimenter, but it is possible that a detailed study of the functioning of telephone receivers in general may lead to improvements as the result of a better understanding of the principles involved. In the case of head receivers there is certainly scope for the experimenter, and particularly for those who are interested in long distance reception, as often the utmost efficiency is necessary under the particular conditions existing at the moment. This at once brings in consideration of the size of the receiver. One would not expect a small diaphragm to emit a large volume of sound, and neither would one select a large receiver with heavy parts to respond to very feeble sounds. It becomes necessary, therefore, to divide receivers into two classes, loud speakers and the others, which are usually of the head

receiver type. It is proposed to consider here only the latter, as the design of the loud-speaking receiver is a subject in itself. Referring, then, to head receivers only, we are again faced with a division; those for ordinary concert use, and those destined for the reception of weak signals and feeble speech or music.

The receiver for concert use—that is, one which is given electrical energy of sufficient magnitude to reproduce sound of approximately the volume usual with line telephones, does not call for great attention at the moment. The conditions in this case are so nearly those obtaining with line telephones that a receiver, as designed and produced by any one of the well-known manufacturers of telephone receivers, will function so perfectly as to leave little room for improvement—that is, of course, provided it is properly applied to the circuit. This proviso is added intentionally, and refers chiefly to the fact that in the majority of wireless circuits the H.T. supply is conducted *via* the head receivers, and is varied in magnitude to suit the valve and not the receivers. This is a condition which would shock a critical telephone engineer. If the magnitude of this H.T. current be known, and could remain unaltered, the position would not be so acute as steps could be taken to allow for its polarising effect. The importance of securing the correct value of the magnetising force of the polarising magnets is often overlooked, and it is interesting to study for a moment the principles of polarisation. In the case of the receiver, which we will call the "sensitive" receivers, to be used for weak signals and feeble speech, the intensity of the polarisation is of considerable importance, and as it is in these that the highest possible efficiency is desired, the following comments are intended to apply more directly to this pattern.

In dealing with the theory of operation of the receiver, or in attempting to discuss the effects of a slight change in current in the receiver circuit, one must go cautiously, as the effects are complicated. It will be realised that the degree of permeability of the various components of the magnetic circuit will determine the amount of change of flux, and the instant the diaphragm responds, the reluctance of the magnetic circuit will be changed, which in turn again affects the flux. This latter change is itself complicated owing to a possible composite effect of the electro-magnetism, and the so-called permanent magnetism of the polarising magnet. When considering the effects on the diaphragm the two "square" laws come more or less into operation. The first, that the pull on an armature is proportional to the square of the intensity of the magnetic force in the air gap between the armature and the pole, and the second, that the force of attraction between two poles is inversely proportional to the square of the distance between them. Without going so deeply into the matter, however, it will be sufficient now to state that an increase in current through the

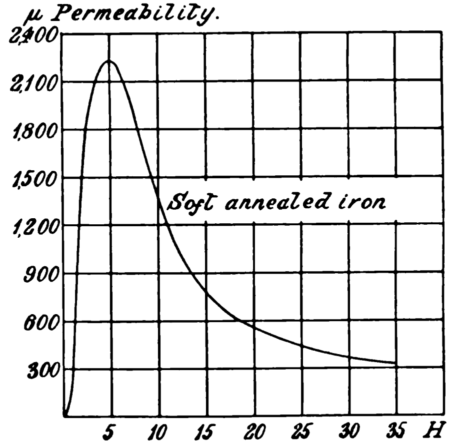


Fig. 2.—Permeability curve for soft iron.

receiver windings will produce an increase in the pull on the diaphragm, which in consequence will move slightly towards the magnets. Now the component of the total current passing through the receiver, effective in moving the diaphragm, may, in its simplest form, be represented by a sine wave curve as in diagram A, Fig. 1. Such current would, in the case of a non-polarised receiver, produce motion in the diaphragm roughly in accordance with a flux variation, as indicated in diagram B, Fig. 1. This is chiefly of theoretical interest, but in passing, it might be mentioned that mathematically it would appear that such a receiver would produce a note an octave higher than that represented by the impressed wave, and Herr J. W. Giltay claims to have proved this experimentally. Diagram C, Fig. 1, is

of more practical interest. Here is shown the possible motion of the diaphragm or armature where a certain amount of polarisation exists. In this case the polarisation represented by H is small compared with the magnetic effect of the speech current represented by h. It will be seen that an extraordinary amount of distortion results, and where the ampere turns or magnetising force due to the windings are such as to approach in magnitude the magnetising force of the polarising magnet, such a condition might easily arise. As an example, the case might be quoted of an average head receiver so connected to a valve circuit that the effect of the steady H.T. current opposes the polarising magnetism. When the H.T. current assists the polarisation, as it always should whenever the circuit is such that a steady current is allowed to

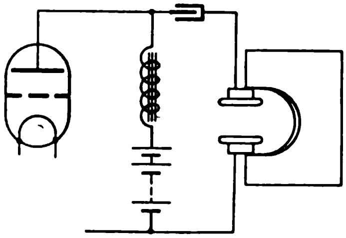


Fig. 3.—An arrangement to remove the steady component from the telephone circuit.

traverse the windings of a receiver, the conditions are, of course, quite different, and the diagram then takes the desired form, as shown in D, Fig. 1.

Having seen graphically the influence of the polarising magnets, it is interesting to note its importance numerically. Using H and h to denote the strength of the magnetic field in the air gap due respectively to the polarising magnet and the peak of the speech current, we have the change in the force of attraction equals $(H+h)^2-(H-h)^2$. This is because the attraction between a magnet and its armature is proportional to the square of the intensity of the magnetic field in the space between. The above expression simplifies to $4Hh$, which shows in a marked manner the importance of having a high degree of polarisation. It is interesting to note that without polarisation the expression becomes, not $4Hh$, but simply h^2, and when h is small, the effect being proportional to its square must be very small indeed. Usually, of course, H is very large compared with h, often several hundred times, and thus $4Hh$ becomes a formidable amount.

Reasoning in the foregoing manner, it would appear desirable to increase H as much as possible, but unfortunately other factors enter into the problem. Fig. 2 is a typical permeability curve for soft iron. From this it will be seen that the permeability varies very considerably according to the intensity of the magnetising force. At very low values the permeability is low, also at high values the permeability falls off in a marked manner. This fact is likely to have an appreciable influence on the action of a receiver, and should be studied in some detail. Considering the magnetic circuit of a receiver we have three main components: magnets, air-gap and armature or diaphragm. The first is a doubtful quantity, as it is usually composed partly of steel and partly of soft iron. The extent to which the steel portion enters into any rapid flux changes depends upon the design of the receiver, and, to avoid going too deeply into detail, it is proposed to ignore the steel, and assume the magnetic circuit to contain only iron and air-gaps, the latter including the leakage flux in the return circuit. Of this circuit the diaphragm is the portion most likely to become saturated, and, therefore, its permeability will be lowered with increasing polarisation. As a result, it will be less susceptible to any slight change in strength for the speech or signal current. The importance of this loss of susceptibility will depend upon the relation and proportion of iron to air-gap in the particular design under consideration. This then brings us to the study of the effect of the air-gap on the sensitivity of the receiver.

Many receivers are arranged with a mechanism whereby the air-gap may be adjusted whilst the receiver is in use. If receivers were always used without any direct current flowing, such means of adjustment would be unnecessary if the receiver was correctly proportioned in design. Where D.C. does flow, it is often possible to effect an improvement in reception by adjusting the air-gap in this manner. Reducing the effective length of the air-gap will, of course, reduce the reluctance of the magnet circuit. This will give rise to a greater total flux for a given magnetising force or ampere turns, and

together with the effect of the "square" laws, previously mentioned, will result in a very considerable increase in pull on the armature. Here the mechanical aspect of the subject arises, and it is not unreasonable to expect that there is a definite minimum air-gap for a diaphragm having a definite diameter, thickness and elastic properties. One can imagine a receiver with weak polarising magnets having the air-gap reduced almost to the point at which the diaphragm will lock. In the extreme, this cannot be fully efficient, and thus we see that to secure maximum efficiency it is desirable to have the intensity of polarisation under control. In the case of receivers tuned for sensitivity, therefore, both the air-gap and the magnetisation should be under control.

If it were possible to provide steel magnets of ample strength, a piece of iron arranged as a magnet shunt would give the desired means of adjustment. Another and perhaps better plan would be to use an electro-magnet for polarising the receiver in place of the usual steel magnet. Adjustment of the current in this would then give complete control. Both the above-mentioned methods necessitate the construction of special receivers, but by exercising a little ingenuity the intensity of polarisation of ordinary receivers could be controlled within reasonable limits. If this is to be attempted it is advisable first to

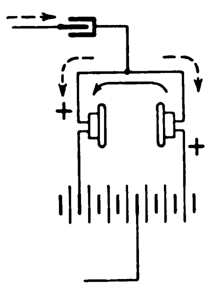


Fig. 4.—Showing how a local magnetising current may be provided.

arrange the receivers so that they may be independent of the steady plate current as supplied to the last valve. The usual manner in which this is accomplished is shown in Fig. 3. A transformer could be used, but it is probable that the choke method would have a higher efficiency and, moreover, greater freedom from distortion. Generally, no great importance is attached to the valves of the choke and condenser used in this circuit, except to specify a choke having an inductance of, say, 2 henries, and a condenser of about 0·25 mfd. The writer would venture to suggest that in such a circuit the value of the capacity of the condenser is of considerable importance. Seeing this condenser is in series with the receiver, the impedance of

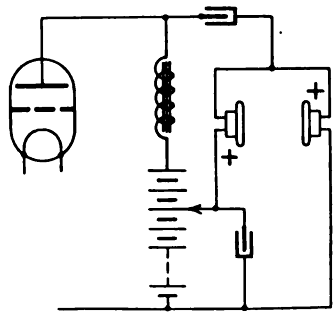


Fig. 5.—The magnetising current is provided by the high tension battery.

the circuit as a whole, to current at speech frequencies, is materially affected, and by selecting a condenser of suitable value it should be possible to adjust the impedance of this output circuit to the value most suitable for the valve. In this way distortion could be avoided and the utmost efficiency secured. However, this is somewhat irrelevant at the moment, and we will assume the circuit to be as shown in Fig. 3. Now by connecting, as shown in Fig. 4, two receivers similar in design and magnetic properties, with their polarity correctly arranged, it is possible to pass a steady direct current of the desired value in the local circuit by adjusting the number of cells. This, then, gives a means of controlling the value of the total polarisation by adding or subtracting a small magnetising effect due to the local current. It will be noticed that with 10,000 turns on the receiver, a current of 3 ma. will give 30 ampere turns, and thus the variation available is quite considerable.

A convenient method of obtaining the same effect without using an additional battery is given in Fig. 5. The ordinary H.T. battery is used to supply the current, and a condenser is added to avoid the possibility of noise arising from the battery.

The Manufacture of High Resistances for Wireless Receiving Circuits.

Although the grid leak is the most usual application of high resistances for wireless purposes, non-inductive resistances are universally employed throughout wireless receiving and transmitting systems. Below will be found details of the manufacture of resistances capable of carrying considerable currents with a reasonable degree of constancy.

THE use of high resistances in receiving circuits originated with the popular type of valve rectification known as "cumulative grid rectification," or "leaky condenser rectification." This method consists of connecting the grid and filament of a valve to the supply of energy requiring rectification, and allowing the impulses to be stored up in a small condenser inserted next to the grid, thus lowering the grid potential. This would cause the grid to assume some large and indefinite negative potential, but is prevented from doing so by connecting a high-resistance leak across the condenser, which allows the charge to leak away and the grid to be brought back to zero potential ready for the next train of impulses. The value of this resistance should be of the order of a megohm, more or less, and is known as the "grid leak."

One of the first things used as a makeshift for these grid leaks was a few lines drawn with a pencil across paper, wood or some other convenient substance. Amongst many other devices pressed into service was blotting paper soaked in Indian ink, which is now the favourite "home-made" grid leak. All these have one disadvantage in common—they are all more or less "noisy" and variable, due to the fact that there is no absolutely continuous path for the current. The conducting material is carbon, and this is mixed with foreign substances, so that, in the case of Indian ink on paper, two minute pieces of carbon carrying current are placed next to one another on the paper, but are not quite touching; consequently, as current passes, it does so with a small spark—a number of these small sparks setting up microphonic noises.

It was with a view to absolute "silence" and constancy that S. R. Mullard evolved his patent "carbonised cellulose resistance." This is, in effect, a stick of pure carbon of suitable resistance, conveniently mounted in a small tube. Its manufacture will be described later.

Modern commercial resistances may be broadly classified under four headings:—

(*a*) Graphite.
(*b*) Colloidal carbon.
(*c*) Solid carbon.
(*d*) Metal.

Under (*a*) may be grouped the original pencil lines on wood and the many forms of compressed graphite mixture which are to be found on the market to-day. It may be mentioned in passing that the writer has recently tested some graphite resistances originating from Germany. These seem to be extremely sensitive to voltage—a resistance marked 2 megohm at 110 volts would vary between 2 megohms at 250 volts up to about 80 megohms at 7 volts. Of course, they were quite unsuitable for use as grid leaks.

Under (*b*) are grouped those resistances which consist of cardboard, blotting paper, etc., soaked in Indian ink.

The disadvantages of resistances falling into these two groups have been pointed out previously—they are microphonic and some of them very unreliable, because in no case is there a continuous path through the resistance.

To group (*c*) belongs the carbonised cellulose resistance of Mullard. This is made from a bundle of cotton fibres, which is first of all parchmentised in order to hold it well together and make it rigid, after which it is carbonised and takes the form of a fibrous carbon stick, like a stranded cable. These resistances are proportional to length; they have perfectly even conductivity, and hence are perfectly "silent."

In the last group (*d*) is the spluttered metal type of resistance. This consists of some sort of glass tube on the walls of which platinum is spluttered by means of an induction coil. The result is, in appearance, like partially smoked glass.

It makes an excellent resistance, and, when properly prepared, should be quite silent; it will also take a comparatively large current, and shows no tendency to over-heat.

The great advantage held by this type over carbon resistances generally is that it possesses a low positive temperature coefficient, whereas that of the carbon types is high and negative.

The advantages are, unfortunately, outweighed by the disadvantages which are: (1) High cost; (2) easily broken; (3) the platinum tends to flake off the glass, thus causing the resistance to increase with age.

Another use for resistances is in the anode circuit ot resistance—capacity coupled valves. The values of these "anode resistances" are usually from 50,000 to 100,000 ohms, and they are required to carry more current and to withstand a higher voltage than grid leaks. The average working anode current of a small receiving valve is about 0·4 milliamps.—supposing an 80,000-ohm resistance to be used, this must carry 0·4 milliamps. and the voltage drop across it will be 32 volts, *i.e.*, it must dissipate 13·8 milliwatts; also the high tension must be increased by 32 volts to allow for the drop in resistance.

In considering the suitability of the various types of resistance for anode resistances, the same remarks apply as for grid leaks, but, in addition, the fibrous carbon is capable of withstanding a much greater current than any of the other types, with the exception of the spluttered platinum. Also the shape and size of the resistance now becomes of some importance. Where a resistance capacity coupling is used the amplification obtained depends upon voltage drop across the resistance, which is communicated to the grid of the next valve: supposing the resistance to have self capacity, such as a wire resistance would have, this self capacity will act as a by-pass and reduce the effectiveness of the resistance. For example, let the resistance be 100,000 ohms and its self capacity be 5 micro-microfarads, then the self capacity would, at 1,000 metres wavelength, carry as large a current as the resistance, thus halving its effectiveness. Self capacity in a resistance is equally disastrous when shunting high-frequency transformers by resistances.

The value of an anode resistance depends mostly upon the type of valve with which it is used—some people prefer the value to be twice that of the impedance of the anode

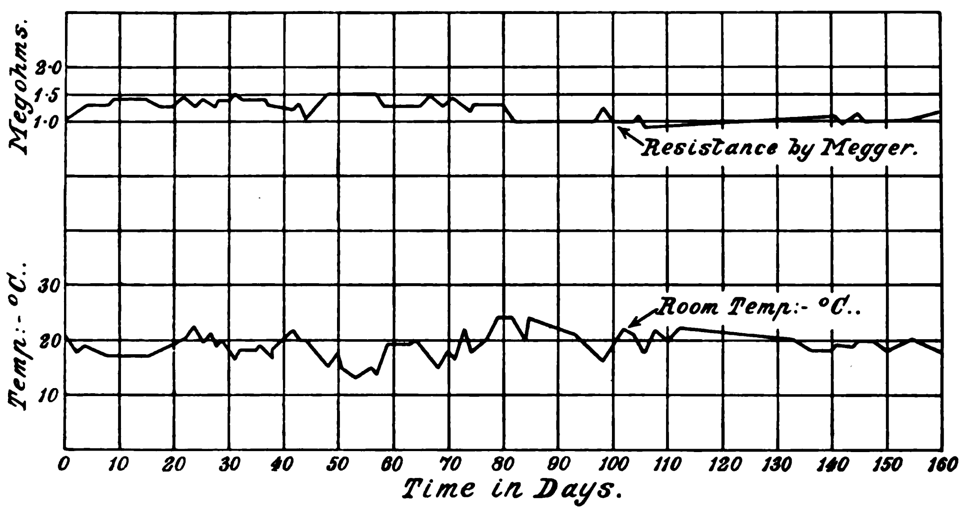


Fig. 1—Showing the resistance of the carbonised cellulose variety measured at intervals under different temperature conditions.

path, but this is generally not known, and the characteristic curve of the valve is not always available. For general purposes it will be found that a resistance of 70,000 or 80,000 ohms will give good results either as an anode resistance or as a high or low-frequency transformer shunt. It must be remembered however that, when using a resistance in the anode circuit of a valve, more high tension should be used to compensate for the voltage drop in the resistance.

The type of resistance used in high frequency circuits should be of a design giving the least self-capacity, and, in practice, a resistance rod ¼ in. in diameter and about 1½ ins. in length is found sufficient. Inside this is a fibrous carbon rod 3-32nd in. diameter and about 1 in. long, held axially and filled round with paraffin wax.

As has been already stated, Mullard resistances are made from carbonised cellulose. The raw material is cotton in the form of a rope having about 250 strands forming a loose bundle about 5-16ths in. in diameter. This is passed slowly through a bath of sulphuric acid, where it is partially digested. From the acid it is drawn on to a drum in water, and has now a stiff and jelly-like appearance, *i.e.*, it becomes parchmentised. It is then thoroughly washed to remove superfluous acid, and hung up on a screen to dry. Weights are tied to each end in order to stretch it. When thoroughly dry the parchmentised cotton has shrunken considerably in diameter and has become stiff and tough—welded together, so to speak. It is then cut up into suitable lengths.

A section through one of these "waxed threads," as they are called, reveals a number of wax-like strands—in fact, similar to the cross-section of a stranded cable.

The threads are then carbonised by packing with graphite in metal cylinders and roasting in an electric furnace. This results in a stiff piece of carbon having a resistance proportional to length—the overall resistance varying according to requirements. For a 2-megohm resistance the threads would be furnaced so as to give carbons having a resistance of about 2 megohms for a 1-in. length.

A section taken through the carbon and magnified would show a great number of carbon threads welded together. A current traversing the section would have open to it innumerable parallel paths through the threads. This ensures a perfectly even and unobstructed flow of current, and is the secret of the perfectly silent working of these resistances.

The carbons from the furnace, having been broken up into inch lengths, are then measured and sorted out into their different values. Next, wires are wound round the ends of the carbons and pasted with special paste to ensure a perfect contact between wire and carbon. The paste is dried and the wired carbons are passed on to another instrument, where they are re-sorted and the values immediately required are put into tubes and passed on to be assembled. The resistances are then soldered to one end cap, the tube filled with the best-quality paraffin wax, and the other end cap is fitted and soldered.

The assembled resistances are then cleaned and sent to another instrument, where they are sorted out according to their values and then sent to the labeller. Having been labelled, the resistances are again tested for value and length to ensure that they are correctly labelled and to specification.

It is usually of interest to know what tests such commercial articles are required to pass. All Mullard resistances are tested with 250-volt meggers; this ensures that they will stand up to ordinary working voltages, which, as a rule, are negligible in the case of grid leaks, and seldom greater than 100 for anode resistance. They are made to within 20 per cent. of their nominal value, as shown by the label, and these limits are rigidly adhered to. All resistances undergo four megger tests during the process of manufacture, particular care being taken to discard any completed resistance or carbon which shows any sign of abnormality in current-carrying capacity, etc.

These resistances keep their values permanently, and are practically indestructible unless very badly treated. A typical life curve is given showing daily tests at 250 volts over a period of about six months.

The Reflex.

So much literature has recently appeared relating to dual amplification circuits, that we are giving below a summary of the development of reflex work, together with practical data, so as to enable the experimenter to grasp the position.

THE present "boom" in reflex circuits is a good example of the way in which original work is overlooked, in view of the fact that such circuits have been quite well known for many years.

To be precise, we find among the patents now owned by the Marconi Company, No. 8821 of 1913, granted to W. P. Thompson, communicated by the Ges. fur Drahtlose Telegraphie, of Berlin, which covers a typical reflex circuit. A very similar circuit was developed by Captain Round in 1915 for use with the Round Valve, and was extraordinarily efficient. It will be remembered that this valve had a very high μ, and the results with the—as it was then called—"Dual Amplification" circuit and the carborundum detector were fully equal to a normal three-valve circuit of the present day.

At about the same time Marius Latour was doing excellent work on similar lines, and during the years 1918-1922 much work was done and published by Grimes in America and Voigt in England. There was also much experimental work by others who have not published their results.

It is taken for granted that all readers of EXPERIMENTAL WIRELESS know already the main idea of reflex working. But those who have not yet tried out such circuits appear to ask such questions as the following:

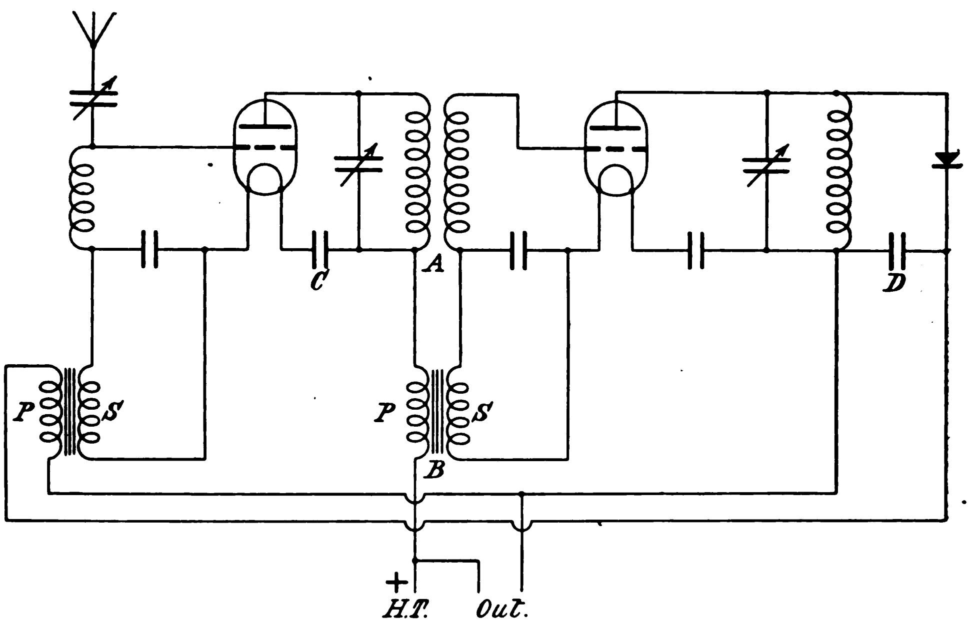


Fig. 1.—The simplest reflex, the direct, in which both H.F. and L.F. go through the valves from left to right.

(1) What will a reflex do as to power, compared with straight circuits on the one hand and "super" circuits on the other?

(2) What about distortion?

(3) Is a reflex reasonably easy to handle?

(4) What are the important points of design?

We will try and answer these queries,

basing our statements on a personal experience from 1915 onwards.

(1) As to power, one can best state it by comparison with another set of the same number of amplifying stages—remembering that the detector valve in a normal set is often counted (wrongly, we think) as a "stage." Thus a three-valve straight set has two amplifiers and a valve detector. If it is of the popular 1 H.F.—1 L.F. type, it is directly comparable with a one-valve reflex with valve detector; and the reflex will probably give about 10 per cent. less power—using, of course, only two valves to do it.

As to comparison with super-regenerative sets, we do not like to speak too positively. Our own experience is that on 300-400 metres a two-valve reflex gives practically the same power as a two-valve Armstrong, much better tone and easier handling. But we have done much more work with the reflex than the Armstrong, and possibly a super-regenerative expert might get better results with the latter type.

(2) Our experience as to distortion is that the reflex differs in no way from a *similar* straight set. We say "similar," for an important point is involved. The reflex does

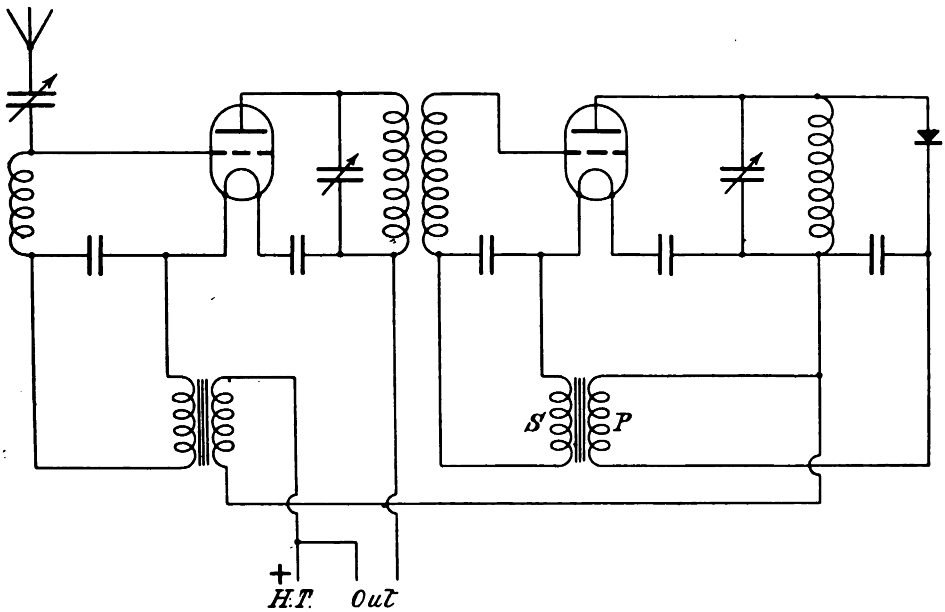


Fig. 2.—In the inverse system, the H.F. goes from left to right, while the valves are used in reverse order for L.F. amplification.

A notable point about the reflex is that the detector valve, if used, cannot be made to "doubly magnify"—at least, not to the writer's satisfaction. The type lends itself particularly well to crystal rectification. This has real advantages, as will be explained later. Generally speaking, a one-valve reflex with crystal detector has a power between a two and a three-valve straight set; a two-valve reflex with crystal comes between a four and a five-valve normal set. The three-valve reflex, *if skilfully designed*, is better than a six-valve normal, but it is not an easy set to design or handle.

not lend itself to tuned anode H.F. coupling. As a rule, one has transformer coupling and no grid condenser and leak. Now, grid rectification is notoriously a source of distortion, unless special precautions are taken; hence a reflex gives a much better tone than the average valve set. If, however, a straight set is designed carefully to avoid this difficulty on the H.F. side, and uses anode rectification, there is nothing to choose; and if resistance coupling is used for the L.F. on the straight set, and transformers for the reflex, the straight set will probably be the better.

In other words, purity is a matter of

design in either case. If both sets are carelessly designed, the reflex is likely to be the better.

(3) This point, ease of handling, is again a matter of design. The reflex having as many H.F. stages as L.F. tempts one to work for selectivity. For example, in the author's favourite two-valve set there is a tuned aerial circuit, a tuned intervalve circuit, and tuned valve to crystal circuit; and reaction is used across the second valve. Naturally, the set is very selective, and accurate tuning is needed. But this is not by any means a necessity. The selectivity may be reduced, and reaction done away with.

It is, however, found important to include grid bias among the adjustments, although it is not used frequently.

With regard to stability, an ordinary reflex is very much on a par with any other set containing several H.F. stages. This matter will be further dealt with later when discussing inverse and direct reflex circuits. On a full-sized aerial a two-valve reflex is a perfectly stable set, not even requiring skill.

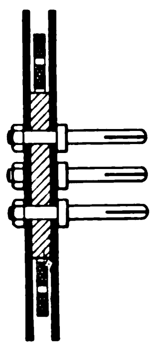


Fig. 3.

Fig. 4.

Fig. 3.—A successful design of H.F. transformer for plugging in. It has a low inter-winding capacity.
Fig. 4.—In a radio choke, the overall size must be kept small to avoid self-capacity.

On a frame or small indoor aerial care must be used to prevent the first valve oscillating. As will be seen from the diagrams reproduced in these pages, the crystal detector comes across the anode coil of the second valve, and its damping action stabilises this admirably.

A three-valve reflex is always likely to be a tricky set. It comprises three stages of L.F. amplification. This means that a fairly powerful valve must be used for the last stage—say, an L.S.5, or its equivalent. But this valve is also doing H.F. work, and it may not be really well suited to this purpose. Further, the amplification is so high that any error in design or construction is likely to result in instability or noisiness. In actual practice a two-valve reflex is of ample strength for any ordinary work. If particularly powerful loud-speaker results are

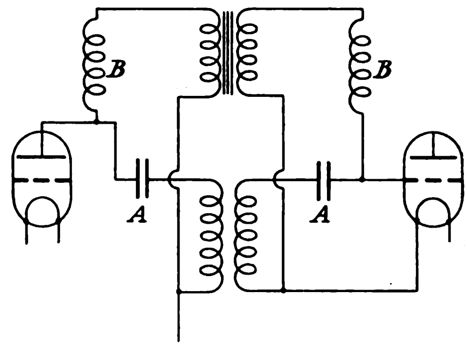


Fig. 5.—An alternative arrangement for the coupling, in which H.F. and L.F. are in parallel.

required it is simplest to add one stage of separate power amplification (L.F. only).

One point as to which there is misconception is the reliability of the crystal. Naturally if one uses galena, requiring a delicate contact and set in a badly-designed detector, there will be trouble. But by using a well-made detector with arrangements for steadying the point, or by using a molybdenite or perikon detector, the difficulty is made non-existent. The author's two detectors are adjusted on the average about once in three weeks, and then usually only in an effort to achieve perfection—not because they are really off.

(4) Now as to design. It must be realised that the design of any set—reflex or other—is a large job if it is to be done properly. One or two points about the reflex need special consideration. Firstly, the right valves and their adjustments. The designer must never forget that for the same strength of audio output the valves are doing more work in a reflex. Take, for example, a one-valve circuit. If the input has an amplitude which we will call A, then the H.F. output for the crystal (using an ordinary valve with $\mu=6$) will be about 4A. This will be converted by the crystal circuit to an L.F. output of smaller amplitude, say A again, which is amplified

by the L.F. transformer (as regards voltage) to perhaps 2A, and delivered to the phones after a final amplification to, say, 10A. So that the valve has a total input of 3A (H.F.+L.F.) for an output of 10A. If it were the last valve of a three-valve set with an output of 10A, it would have an input of 2A only. In other words, the valve to be used in a reflex must be able to deal with a larger input for the same audio-frequency tor the inverse is even further from equal input to the various valves, thus:

Valve No. ..	1	2	3
H.F. Input ..	1	4	16
L.F. Input ..	1,600	160	16
Total	1,601	164	32

If a direct circuit were used the third valve would carry 1,600+16=1,616 units of input, so that the valve used need only be of

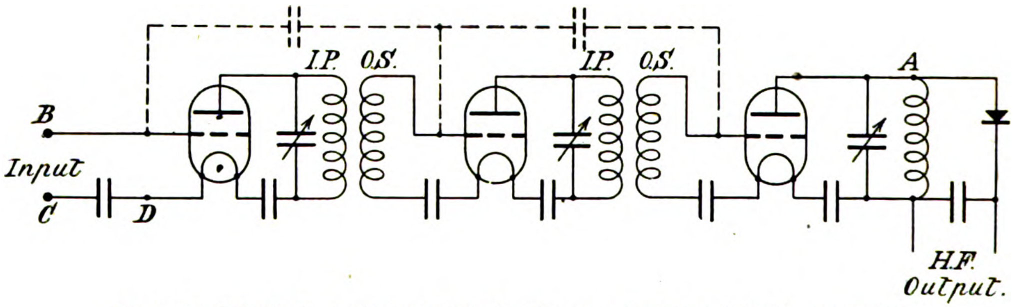


Fig. 6.—The H.F. circuits of a three-valve set—the idea can obviously be extended to any number.

output. An approximate estimate of the increase can always be made quite easily as above.

Another important point of design, in a set comprising more than one amplifying valve, is whether to use a direct or inverse circuit. The difference is shown clearly by comparison of Figs. 1 and 2, which show the two types simplified by the omission of batteries, etc. There are points to be made in favour of each type, but the author is firmly convinced that for normal conditions, especially if long wave work is to be catered for, the direct is superior. None the less, the inverse has important advantages, so that the point merits discussion.

A claim frequently made for the inverse is its great advantage in equalising the load on the two valves, the largest H.F. input going to the valve carrying the smallest L.F. But this does not always work out in practice. In the case of a two-valve set with crystal detector, we are likely to have the following inputs: 1st H.F. 1; 2nd H.F. 4; 1st L.F. 1; 2nd L.F. 10. In a direct set the first valve will have a total of 2, and the second a total of 14; in an inverse the inputs will be 11 and 5.

But in a three-valve set with valve detec- 1 per cent. greater capacity than the first in the inverse—a quite unimportant difference.

A really important point is in perfect separation of H.F. and L.F. currents. Taking, for example, the intervalve circuits of Fig. 1, in theory the H.F. current is transferred *via* A, and the L.F. *via* B. But in practice there will be a certain transfer of L.F. energy *via* A, and owing to the self and mutual capacity of the windings of B, and the fact that the by-pass condenser C is not infinitely large, there is also a transfer of H.F. energy *via* B. Now in this particular case it does not matter—either transformer transfers energy from the first to the second valve. When, however, we come to consider the intervalve circuit of the inverse, we find that H.F. energy from the anode may leak back to the grid *via* the L.F. transformer, while L.F. energy, which is intended to be transferred towards the left in the figure, may leak back towards the right *via* the H.F. transformer.

When the H.F. and the L.F. frequencies are of the order of 1,000 and 1,000,000, as in the case of short-wave work, this leakage is not serious; but for longer waves it rapidly becomes important; so much so that at 15,000 metres (N. equals 20,000)

an inverse set is prone to oscillate continuously.

A possible way to avoid this is by substituting for the by-pass condensers a set of properly designed filters. But this means quite a complicated set. Should this trouble occur on a direct set it can be overcome by a single filter at the point B to prevent H.F. leaking back to the first valve, while in the inverse each anode circuit needs a filter.

On the other hand, the inverse has a real advantage where there is likely to be audio-frequency interference—tram lines near the aerial, etc. In the direct set any such L.F. interference passes through the set and is considerably magnified. In the inverse, on the other hand, it only passes through one L.F. stage, and is, therefore, not so troublesome. The only way of avoiding this difficulty, if it is serious in the direct system, is to use No. 1 valve as H.F. only.

Perhaps the next important point to consider is the type of intervalve coupling to be used. In his own practice the author has standardised simple transformers as shown in Figs. 1 and 2. The L.F. transformers are of normal type, carefully chosen. Since Some of the cheap transformers now available have performed excellently.

With regard to the H.F. transformers, the design found most successful has close coupled windings of 1 to 1 ratio, either winding being shunted by a tuning condenser. As an example, the range from broadcast band up to 600 metres is well covered by windings of 50 turns each, internal diameter one and half inches, shunted by a ·0005 μF. variable. Windings of 2,100 turns each cover the highest wave-length used. It has been found advantageous to design the transformer so that the interwinding capacity is low. A satisfactory type is that shown in Fig. 3, in which it will be seen that the windings are edge on to one another. They are separated by twenty turns or so of cotton thread.

If selectivity is not specially desired, there are distinct possibilities in resistance coupling. The one difficulty is to find a satisfactory value for the grid condensers. These have to be large enough to pass L.F. currents fairly freely, but if they are too large, there may be trouble owing to the large time constant of such a condenser with the necessary resist-

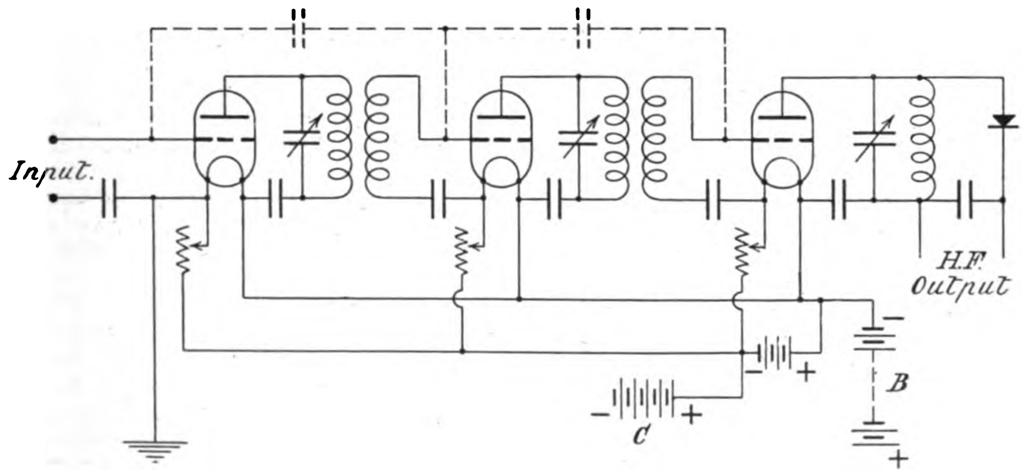


Fig. 7.—The set of Fig. 6, with the filament circuit and batteries added.

their windings are all shunted by condensers it is desirable to choose a make having naturally a low self-capacity, as otherwise the addition of the outside condensers may give a muffled tone owing to partial shunting of the high harmonics. There is, however, no serious trouble in getting suitable types.

ance. For example, a suitable value for L.F. resistance coupling is ·1 μF. But this with a 1 MO. grid-leak gives a time constant of ·1 sec., which means that any accumulated charge would paralyse the valve from the H.F. point of view. This difficulty may be avoided by preventing any such accumula-

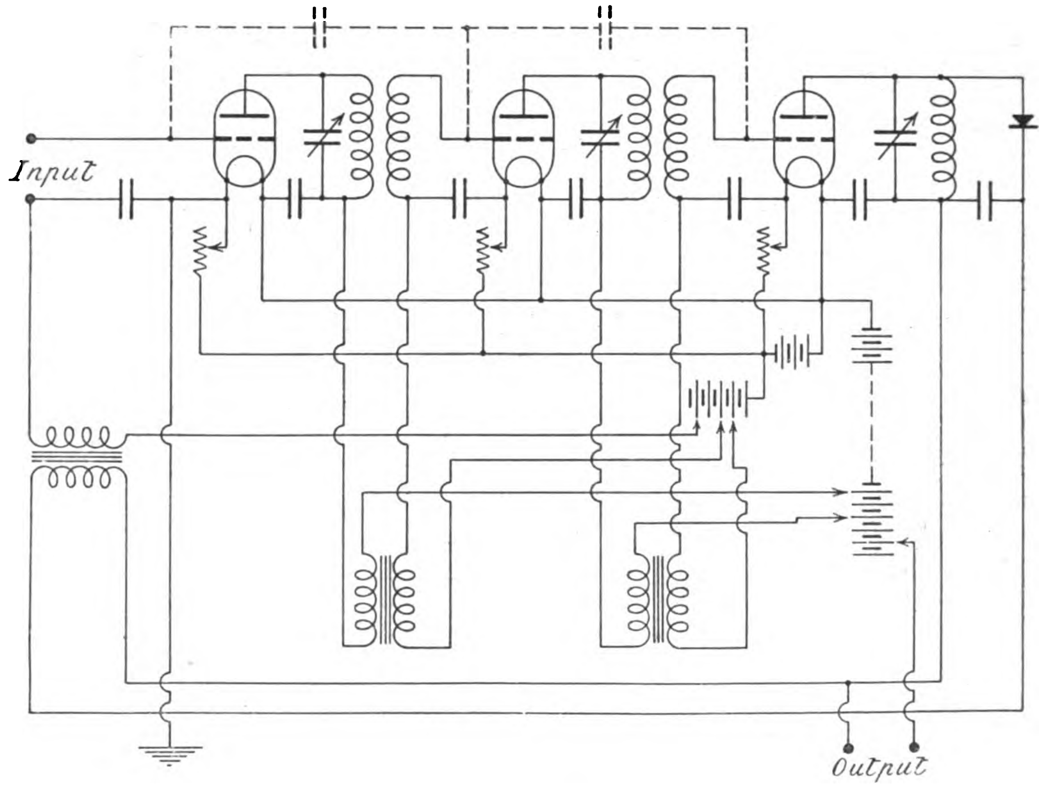


Fig. 8.—Here is seen the complete wiring scheme, except for aerial tuning.

tion. It will be remembered that the valves in question are pure amplifiers. No grid current is, therefore, needed, as it would be for detection. The sole object of the condenser is to insulate the grid from the preceding plate. The lower end of the leak may, therefore, be connected to a grid bias battery of such value that grid current is non-existent, under which condition a large condenser may be used. The writer has not experimented largely with this type of circuit, but such tests as he has carried out seem to indicate that a grid condenser of ·01 to ·05 μF. is about the right value.

It is quite feasible to substitute chokes for the resistances, with a considerable saving in H.T. supply. The only difficulty is that a choke of sufficient value at audio frequencies will probably have too much self-capacity to be valuable at high frequencies. It is, therefore, usually necessary to use two chokes in series, the one nearer the anode being a radio choke of very low capacity, the other an iron core audio choke.

A suitable design for the radio choke is that of Fig. 4, which is about natural size. The windings should be of the order of 5,000 turns of 47 S.W.G., giving an inductance of 200,000 to 500,000 μH. with a self-capacity of 2 to 5 μμF. The audio choke would be of similar design to the secondary of an L.F. intervalve transformer.

Various circuits have been designed in which resistance or tuned anode H.F. coupling is combined with transformer L.F. coupling. The writer has not been able to get really successful results with these, so they are not reproduced. There is considerable field for experiment here for those interested.

Returning to the type most familiar, that of Figs. 1 and 2, in which transformers are used for both frequencies, the next question is the choice between series and parallel arrangements of the two couplings. The series arrangement has already been discussed; the parallel is shown in Fig. 5. L.F. currents are stopped off from the H.F. transformer by the condensers A, of the order

of ·0001 to ·001 μF., while H.F. currents are prevented from leaking through the self-capacity of the L.F. transformer by the radio chokes B, which (for broadcast and similar wave-lengths) might be of 5,000 μH. inductance, with a self-capacity not to exceed 2-5 μμF. A coil of the same type as Fig. 4, but with a coarser wire, giving, say, 300 turns in the space, would be suitable.

It is obvious that the two types of coupling may be intermingled in the same set; one is in no way bound to adhere to one or the other. An advantage of the parallel method is that the stopping condensers, which (for L.F. purposes) are across the L.F. transformers, may be quite small, which may, with some transformers, give a better tone. On the other hand, any leakage past the H.F. choke has a serious effect on signal strength. Under normal circumstances, the author prefers the series method.

Two other points of general design. First, it will be found a great assistance towards stability and ease of operation if the set is earthed at some point on the filament circuit, and steps should be taken to ensure this; second, if valves are to be switched in or out, it is useful to switch them out on the L.F., and leave them in as H.F. amplifiers, or *vice versa*, a matter which needs a little thought. These matters are taken up below.

It will, perhaps, be of assistance to carry the reader through some part of the design as a set, to show the method of approach. Naturally, the type chosen will be that which the author prefers for his own use. We will first lay out the H.F. circuits, of which the simplest possible theoretical design is that of Fig. 6. This practically speaks for itself. It will be noticed that the H.F. circuits are complete, though we shall obviously have to provide some D.C. connection from grids and anodes to filaments.

As has been already stated, the values of constants in the circuit are not critical. In order to save trouble in constant changing of plug-in transformers, the author uses fairly large tuning condensers (·0005 μF.). The transformers are of the type already described. The coil A may be a transformer if preferred, and is then interchangeable with the others. It may be placed so that it is coupled to either of the other transformers if reaction is desired. Neutrodyne condensers (shown dotted) may be added if desired, and are often valuable in steadying the set (the author's experience is that neutrodyne condensers are not, as a rule, very effective on *inverse* circuits).

The crystal circuit comes across the anode coil (or transformer secondary) of the last valve, and the resultant loading has an important effect. A low resistance crystal, passing a comparatively large current, flattens the tuning and stabilises the set. A high resistance type—or even more so, a valve detector—gives the opposite effect. It is found advantageous to use variable reaction by back coupling coil A, to compensate for differences in the crystal, which it does admirably. The transformers should be connected so that the ends most free from mutual capacity (normally I.P. and O.S.) go to grid and anode.

For long waves especially the ohmic resistance of coil A may mean that the steady anode current in it may cause a perceptible D.C. voltage across it, which naturally influences the crystal. A reversing switch is, therefore, useful, also a selector switch for two detectors.

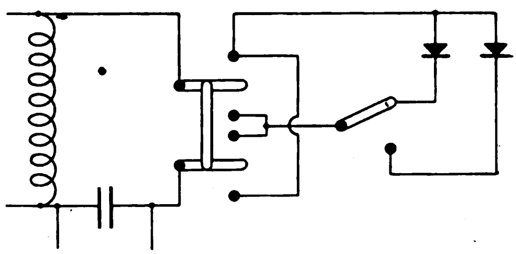


Fig. 9.—Further refinements are the use of a reversing switch and a selector for two detectors.

With regard to the "input" circuit, this may be of any kind, provided that there is a D.C. conducting path between terminals B and C. In view of the advantages of earthing the filaments, it is best to connect the earth of the set to the point D; this throws the first by-pass condenser into the aerial circuit. As its capacity is large, its only effect from the H.F. point of view is a quite unimportant change in aerial tuning adjustments.

As to the size of the by-pass condensers, ·001 μF. is recommended for short waves, ·005 for very long. But except as regards purity of tone in telephony, their exact size is unimportant. For this particular purpose (telephony) it is a matter of suiting the condensers to the L.F. transformers.

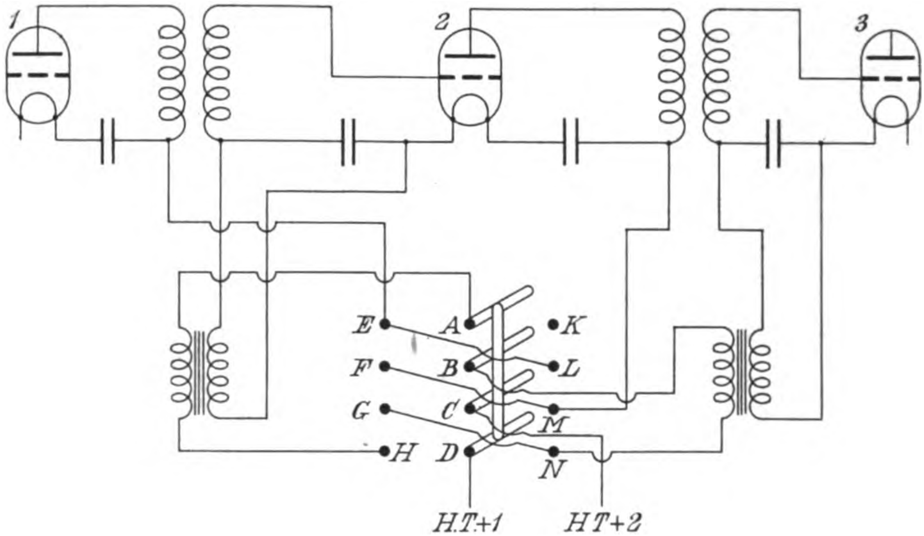


Fig. 10.—To cut out one stage, a four-arm switch must be used, so that the valve can still act for H.F. when cut out for L.F., and vice versa.

The next part of our design is the filament circuit, and this is shown, together with all the batteries, in Fig. 7. It is of the simplest nature. B is the H.T. battery, and C a grid battery. One master rheostat may be used, but is not considered good practice. The rheostats may be in the positive side, if preferred.

All that now remains is to complete the circuit by inserting the L.F. transformers, which gives the complete lay-out shown in Fig. 8. This looks at first sight rather formidable, but a closer inspection will show that it is not so in reality. It could have been made simpler in appearance by joining all the H.T. and grid bias leads, instead of showing separate tappings.

This lay-out shows no switchgear, which is better shown in separate details. Fig. 9, for example, shows the detector switches, of which one is a reverse, the other a selector. Fig. 10 shows the switch necessary to throw out one stage of amplification—in this case a L.F. stage. It will be seen that with the four-way two-throw switch to the left, the anode circuit of No. 1 valve is E.A.H.D., and that of No. 2, M.F.B.N.G.C., giving normal connections. With the switch over to the right the circuits are as follows: No. 1 valve anode E.L.B.N.D., passing through the second transformer primary; No. 2 anode, M.C., cutting all L.F. amplification out of this valve's province, while keeping it in service for H.F.

As will readily be realised, there is endless scope for modification in these circuits, without altering the main principle. It is thought that the suggestions already made will be sufficient to form a basis of experiment. As to the practical lay-out of the set, this also affords some problems. The author has refrained from suggestions in view of the widely different tastes of constructors. It is obviously important to get the H.F. transformers and the by-pass condensers near the valve sockets, with the object of getting short H.F. circuits.

It is obvious that much has to be left unsaid in an article, which can only cover the ground in a sketchy fashion. If the author has succeeded in attracting the attention of the amateur to a circuit of great possibilities he will rest content.

Transatlantic Radio-Telephony.

BY CAPT. ST. CLAIR-FINLAY, B.Sc.

Long distance telephony necessitates, amongst other things, a steady carrier and full distortionless modulation. How this may be obtained is described in the following article, which should be of great practical value.

WHILST much attention is being directed towards short-wave DX telegraphy, and remarkable results are being obtained in this direction by amateurs, comparatively little is now being done by them in the sister science of telephony, probably for the reason that, until the success of long-distance telegraphy on low powers has been fully established, experimenters are naturally more concerned in sheer "getting across" by the most promising means than in attempting more doubtful ones in the success of which they would feel less confidence, and the results already achieved afford ample vindication of this policy. In consequence, there are probably few stations now working DX on either side of the Atlantic specially equipped to do so on telephony, and it is possible that details of one so equipped may be of interest to experimenters in view of the future work that is certain to be done in this direction.

It is therefore proposed to give, not a general description of the station as such, but details of the special means adopted thereat to secure super-efficiency in the long-range transmission and reception of speech on low powers and short waves, together with a brief review of the main facts emerging from research work therein which it is hoped may be of interest; and it should be stated at once that these will refer, not to special directional and side-band systems now under investigation by the writer and others, but to the standard non-directional methods already in use by amateurs generally.

Clearly established by these experiments was the special importance of certain factors in the effective carrying-power of a modulated wave, and these, as far as possible in order of precedence, may be summed up as follows :—

TRANSMITTER.

(1) Radiation efficiency of antenna.
(2) Modulated output to antenna.
(3) Purity of carrier.
(4) Quality of modulation.
(5) Sharpness of tuning and stability of wave.

RECEIVER.

(1) Reception efficiency of antenna.
(2) Sensitivity of receiver.
(3) Selectivity of tuner.
(4) Silent and distortionless amplification.
(5) General stability of circuits.

And it should here be remarked that, whilst these will be recognised by experienced radio-telephonists, and may be dismissed as entirely elementary by some, their supreme importance lies in the very fact that they *are* elementary essentials, and it was found that each and all required development to a point considerably beyond usual practice to make possible the results ultimately obtained.

First of all, since the actual results at the receiving end constitute our entire concern, our first consideration must be to get as much as possible into the *ether*, not merely into the aerial, and as this will very largely depend upon the efficiency of the aerial itself, which, in turn, will largely depend upon its suitability for the wave-length and power used, the first essentials must manifestly be scientific design and careful construction of the antenna system for the purpose in view.

Fortunately, the aerial dimensions allowed to amateurs under P.M.G. regulations are as suitable for work on 200 metres and under as they were unsuitable for the old 1,000-metre wave, and, though few amateurs may be able to work under anything like ideal conditions in other respects, their aerials can in most cases be made, in themselves at least, very nearly ideal for short-wave work, and the influence of this on the results obtainable is, of course, enormous.

Assuming, then, a really good and suitable antenna system, the next consideration of importance is the amount of *modulated* energy delivered to that system, and it

should be realised that it is of little use to produce a large aerial current unless a large proportion also of it is controlled—it is *control* that counts in telephony, not mere aerial current, and 1 ampere of which 80 per cent. is modulated will, for example, be more effective than 2 amperes of which only 35 per cent. is modulated. Therefore, the importance of having a modulator of sufficient power effectually to control our aerial current will be manifest.

At the same time, *quality* of modulation is of the greatest importance in long-distance telephony. Quite sufficient distortion may occur in transit due to atmospherical, topographical, geological and other conditions, as well as in the distant receiver itself when adjusted to the necessary sensitivity, to make the best of transmitted speech none too clear on arrival, and if distorted speech is transmitted in the first instance the result at the receiving end may be wholly unintelligible.

Neither can effectual depth of control be obtained without distortion unless a suitable control system is used, and unless the speech currents delivered to that system be themselves undistorted, and this demands :—

(1) A really good microphone—and it may here be remarked that the ordinary carbon instrument is by no means suitable for this purpose.

(2) A distortionless and silent amplifier—more than one stage coupled with such transformers as are generally available to amateurs is inadvisable, and it is preferable to use resistance or choke coupling.

(3) A pure and ripple-free carrier—smoothing of the H.T. supply requires special attention.

The importance of stability of the carrier itself lies in the obvious difficulty imposed at the receiving end of keeping circuits—probably several circuits—critically tuned to a transmission the wave-length of which is continually varying, and every precaution needs to be taken to guard against unsteadiness or "swing" of the carrier either during or between transmissions—the same, of course, applying at the receiving end and being included under the heading "stability of circuits," this matter being responsible for many of the symptoms commonly designated "fading effects." The last item, *viz.*, sharp tuning of the modulated output, is a matter of efficient transmission, *i.e.*, utmost concentration of the available energy into a definite operating wave-band of least possible width so as to ensure a minimum of diffusion loss, and lies in the correct design of the antenna system for the wave-length used and power handled, correct adjustment and tuning thereto of the transmitter, and the use of oscillation and control systems such as to ensure minimum possible "spreading" of the carrier due to modulation, about each of which much could be said that space unfortunately does not permit of here, the same applying to the effects of actual *wave-length*, which of course is a wide and far-reaching subject.

Finally, it should not be lost sight of that the receiver is just as important as the transmitter—the range and abilities of the one determine those of the other—and it is thought that the special importance of the considerations enumerated under that heading will be realised and understood by readers of this journal without further explanation.

Having now summarised, if perforce very inadequately, the principal lessons emerging from an investigation of the subject, we may now turn to details of the practical means adopted to meet them at the writer's station and a consideration of the actual results achieved thereby.

It being desired, for reasons which the experiments had demonstrated, to operate at the natural wave-length of the aerial, and it being also desired, since DX was the objective, to work on a wave-length clear of the fading-band, a working wave of the order of 150–160 metres was decided upon, and the first consideration was the arrangement of the best possible antenna system for the purpose.

Many different types, sizes and combinations of aerial and lower capacity were tried out, and that giving best all-round results was one of T form, which, however, could not be so conveniently arranged for permanent use as another one of the inverted L type which was practically as good, so this latter, details and diagram of which are given in Fig. 1. was that finally adopted :—

AERIAL.

Type.—Flat-topped, open-ended, inverted L.

Conductors.—Three, .25 in. enamelled copper ribbon.

Spacing.—6 ft.

Spread.—12 ft.

Length of Top.—55 ft.

Down Leads.—45 ft., three-lead convergent.

Height Overall.—55 ft.

Height above Counterpoise.—45 ft.

50 ft. and 42 ft. respectively, allowing 5 ft. maximum sag in aerial and 2 ft. in counterpoise.

COUNTERPOISE.

Type.—Open-ended, flat semi-fan.

Conductors.—Five, ·25 in. enamelled copper ribbon.

Spacing.—6 ft.

Spread.—24 ft.

Length Overall.—100 ft.

In Leads.—Five, convergent.

Height above Ground.—10 ft. (8 ft. at centre, allowing 2 ft. maximum sag).

EARTH.

Three conductors of $\frac{3}{8}$-in. silicon-bronze strip, length 100 ft., spacing 12 ft., spread 24 ft., buried 1 ft., immediately below counterpoise.

ANTENNA CONSTANTS.

$h = 12{\cdot}8$ m. $Rr = 10{\cdot}0$ ohms.

$c = {\cdot}00035$ mfd. $\lambda = 160$ m.

$Rdg = 2{\cdot}8$ ohms.

A larger and taller aerial could quite conveniently have been erected, but this would have brought the fundamental higher than would have been desirable, whilst that described gave most excellent results, and proved scarcely open to improvement for the purpose intended, viz., tran.mission and reception between 100 and 200 metres.

All conductors in aerial and counterpoise are drawn as taut as possible to prevent sway, and are arranged symmetrically and of exactly equal length from lead-in to free end, which was found an important point, whilst insulation throughout the system is very carefully carried out and is proof against all weather conditions and many times the power likely to be used—also an important point.

Insulators of the De-la-Rue ribbed and Buller porcelain type are used, nowhere less than two in series, whilst the leads-in are also of the heavy ribbed type mounted centrally in 15-in. glass plates and protected by drip-cowls, the minimum leakage path throughout the system being 30 ins. Equal care is taken regarding capacity effects, as may be judged from the small capacitance figure of ·00035 mfd. for an antenna of these dimensions; ohmic resistance is reduced to a minimum by the use of enamelled ribbon of high conductivity, which is unbroken and continuous from lead-in to the free end of each conductor, thus eliminating joints; inductive, absorptive and other undesirable effects are minimised by such spacing of the masts, guys, etc., as to ensure absence from the aerial field of foreign masses or conductors nearer than the counterpoise itself, by mounting the latter on posts well outside its own field, and by insulating and breaking up all guy-wires, etc., into three unequal

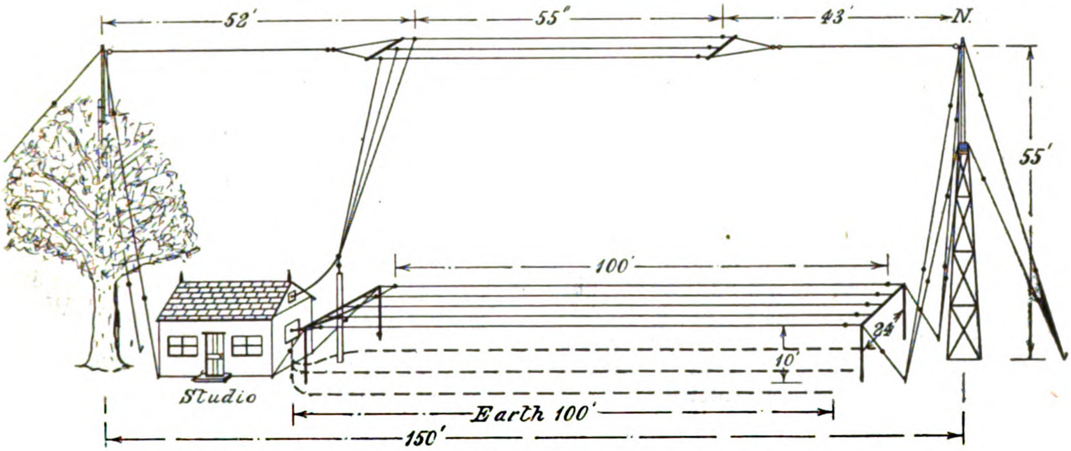


Fig. 1.—Showing general arrangement of the aerial, counterpoise, and earth system.

sections—no rope of any kind being used; and the total losses in the system are consequently very small, R*d* and R*g* together amounting to the low figure of 2·8 ohms, whilst the effective height is proportionately good, the radiation-resistance of 10 ohms being probably exceptional for an amateur antenna.

It is here worthy of note that the total cost of this system—which, whilst admittedly good, may be regarded by some as unnecessarily elaborate—amounted to £10 10s. inclusive of masts, which, considering its supreme importance, is regarded by the writer as a distinctly small and well-justified proportion of the total cost of one's apparatus.

Having now a suitable antenna system, the next item of importance was a really efficient transmitter, and, after experiments with various oscillators, the circuit shown in Fig. 2 was finally adopted and a suitable transmitter built for 100 and 200 metres and 10–100 watts.

This is a peculiar circuit which can best be described as a loose-coupled Colpitts, and is a result of various attempts to combine high efficiency with dead-steadiness of wave in a practical low-power transmitter. Unlike the Colpitts, transfer of energy is entirely independent of the aerial inductance, as the necessary inductance is provided in the transfer-circuit L2-C2, the value of which can be adjusted to the ideal, and any swinging or variation of the antenna constants is without effect upon the transmitter oscillatory circuits, or, therefore, upon the wavelength radiated, although tuning is exceedingly sharp. The circuit is particularly suitable for work about the fundamental, as the degree of coupling required is small, and, operated at the fundamental (160 metres), it is found that five turns each on A.T.I. and coupler suffice for full transfer of energy with suitable inductances, it being possible to work quite close to the natural wave-length of the aerial without necessity for a series condenser if so desired.

In addition to these special advantages, the circuit is highly efficient, input-to-output efficiencies exceeding 80 per cent. being obtainable with a single valve, rising as high as 85 per cent. with two valves in parallel if properly adjusted, operation being at the same time quite stable and adjustments not too critical. The extreme tuning range is 100 to 200 metres.

With regard to actual details of this transmitter, the A.T.I. and coupler are exactly similar coils of the flat spiral type, each 8 ins. square, and consisting of six turns of ¼ in. by 18 gauge stiff copper strip, air-spaced ¼ in. between turns, both mounted together ½ in. apart in a skeleton frame, the coupling being fixed. Aerial tuning is accomplished by a ·001 mfd. series condenser, a similar condenser below the A.T.I. providing the tuned-earth, whilst a third of similar value fine tunes the transfer-circuit. The C.C.I. consists of 22 turns of 16 S.W.G. bright copper wire, air-spaced 3-16ths in. on a skeleton rectangular frame 6 ins. square, with selector-clip, the anode-tap taking the form of a variometer wound with 18 D.C.C. wire, 20 turns each on stator and rotor, these being of 6 ins. and 3½ ins. diameter respectively. The H.F. choke W in the H.T. lead, which also functions as a wavemeter, the tube P ionising when in resonance, is a similar variometer with 52 turns of 20 D.C.C., and a calibrated dial giving direct λ readings. The grid choke is wound with 100 turns of 40 S.W.G. Eureka on a 2-in. former, and a third choke, L7, designed to ensure complete separation of the H.F. and D.C. circuits, is similarly wound with 75 turns of 16 S.W.G. enamelled wire on a 3½-in. former, across which the L.T. voltage drop is negligible up to several amperes. All coils are mounted on porcelain insulators and set well clear of the panel and controls for avoidance of capacity effects, whilst the short aerial and counterpoise leads within the operating room are also kept well clear and are suspended from the roof on porcelain insulators, the leads themselves being of heavy rubber-sheathed high-tension cable.

The calibrated twin-reading 0–2–4-amp. aerial ammeter, having an appreciable resistance when that of the aerial circuit itself is so low, is inductively coupled to the earth lead, whilst the 0–4–8-amp. transfer circuit meter, having a negligible resistance, is connected directly in series with that circuit, the indications of these two meters, which have 5-in. dials readable at a distance, greatly facilitating the accurate resonation and adjustment of the circuits. The pilot lamp P is connected across the H.F. choke,

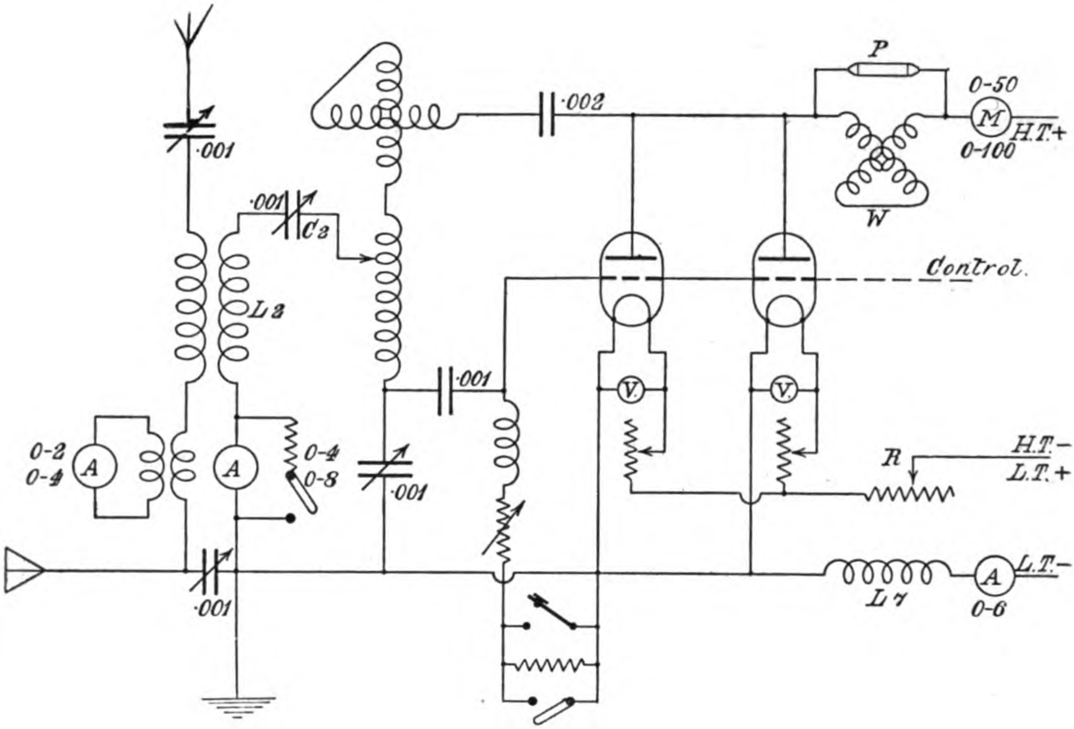


Fig. 2.—The peculiar oscillator embodying several features to meet the special requirements of the transmission.

and this lamp—which consists of a small cylindrical neon tube evacuated to a pressure of 1 cm. of mercury with a small external electrode at either end—whilst absorbing a negligible amount of H.F. current, is brightly ionised thereby, and, owing to the complete absence of inertia, affords sensitive visual indication of the modulation control not readily obtainable by other means, an electro-static indicator of this kind being of special value when the control is exercised equally by increment and decrement, as should be the case in a choke-controlled transmitter. The method of combining the functions of pilot, H.F. choke and wave-meter, enabling the setting of the transmitter to be instantly determined, is original, and may be of interest.

For telegraphy the method of keying may be noted, as this is simple and gives excellent results. It consists essentially in the provision of a two-part grid-leak of such total value as to prevent oscillation of the valves when all-in, due to the excess negative grid-bias cutting off the anode current, and in short-circuiting a portion thereof, by depression of the key, such as to bring the grid-bias to the correct working value. This is a better principle, for example, than complete disconnection of the grid-leak, as the resultant load-changes imposed upon the latter are much less heavy and abrupt, and not only is the leak itself relieved, but undesirable grid-click and "chirp" are eliminated, whilst the key load also is reduced and with it any sticking tendency. Moreover, in the position indicated capacity effects are *nil*, enabling the key to be connected to the transmitter by a length of flex and operated at any convenient distance without impairing the steadiness of note or adjustment of the transmitter, whilst H.F. burns of any consequence are practically impossible from any part of the key, a matter of some importance when any considerable power is in use. The absence of any "spacing wave" is also of practical importance, as the likelihood of interference with other stations is thereby reduced to half.

A suitable value of key leak will usually

be about twice that of the grid-leak proper, this consisting in the present case of a fixed resistance (whether non-inductive, non-capacitive or otherwise is of little moment if arranged as shown) of 30,000 ohms, the grid-leak itself being continuously variable between 2,000 and 20,000 ohms, and usually adjusted to a rather high value of the order of 10,000–12,000 ohms in practice owing to the use of plate voltages somewhat in excess of normal rating and operation on the constant voltage system, which is found advantageous. The key-leak and key itself are, of course, shorted for telephony, and it is important for this purpose that the grid-leak itself be constant and silent under load as a noisy leak can—and frequently does—quite spoil the purity of the carrier.

The transmitter described is suitable for powers up to about 100 watts, above which somewhat larger meters would be required, and forms an almost ideal medium-power set for use over a reasonably limited tuning range, although for ordinary purposes the loose-coupling arrangement would not be necessary and could be dispensed with without much effect on the efficiency, leaving a slightly modified Colpitts circuit particularly well suited to rapid wave-changing should this be desired.

A schedule of the actual outputs, etc., obtained in practice is here given :—

Watts	M.A.	V.	Oscillators	Aerial Current λ 160		
				A	I	E
10	20	500	2 "B"	1·75	·82	·93
100	83	1200	2 0·50	5·50	2·58	2·92

Two valves in parallel are normally used, as this enables a high efficiency to be obtained with considerable valve economy, the valves being run well within their limits and consequently having a long life, though to ensure best results it is very desirable that the filament temperatures be independently adjustable, as shown in the diagram, as no two valves possess quite the same characteristics, though once synchronised (which is done by oscillating them separately and balancing their outputs, etc.) all subsequent adjustments are affected simultaneously at the common control rheostat R so as not to disturb the balance, this being also much quicker and more convenient.

The neon side-tone shown in Fig. 4 may be noted, as this, being free from paralysis, affords really reliable indication of the modulation quality.

The next consideration was the H.T. supply of perfectly smooth D.C. at suitable voltage and wattage, it being essential for the purpose in view that this be both ample and completely free from ripple up to full load.

The house current being D.C. at 100 volts was not directly helpful, though being locally generated by a small hydro-electric plant costing little to run it is used at the station for the charging of the filament and H.T. batteries, the former of which consist of four Exide heavy-duty cells of 120-amps. actual capacity in glass containers, permanently mounted on an insulated rack and charged *in situ* through a resistance charging-board delivering up to 100 watts charging current, the battery delivering up to 12 amps. filament current at 8 volts without overload.

The H.T. battery, consisting of 250 cells of the B.K. type, is also permanently mounted on an insulated rack and charged *in situ* from the same source through a sub-charging panel delivering up to 75 watts charging current at 75 volts, the cells being series-parallelled in blocks of twenty-five for charging, and cascaded on discharge by means of a simple series-shunt switching arrangement, this plant providing a valuable source of perfectly pure D.C. up to 100 watts and 500 volts, and solving any difficulty up to that tension, being used for all the H.T. purposes of the station.

This sufficed perfectly for low-power work, but for greater powers a higher voltage was necessary, and this was provided by a 120-watt power transformer of 1-100 ratio built up from the coils of T.V.T. units, the primary of which is fed with 2 amps. of interrupted D.C. at 8 volts from the filament supply battery *via* a small motor-driven rotary interrupter delivering I.D.C. at a frequency of 400 p.p.s., to which the transformer windings are resonated, and this, after convertion thereby to 800 volts, is rectified and thoroughly smoothed by a special arrangement of neon tubes and a compound filter circuit.

A generator of this type, whilst producing maximum wattage in one direction, produces also a practically wattless half-wave in the

other, the voltage of which may reach up to half that of the useful half-wave, and this "backlash" requires to be completely suppressed either by rectification or polarisation for the production of pure D.C. suitable for telephony. The neon rectifier mentioned is employed only when the generator is used alone for intermediate powers, so need not be described here, the polarisation method being employed for full power, 500 volts from the H.T. battery described above being used for this purpose, this neutralising the backlash and pure D.C. at a voltage equal to generator+battery—circuit-drop being obtained. This is passed through a specially designed filter to eliminate the 400-period ripple, a feature of which is the compensating stalling of the interrupter, and one in the H.T. supply lead blowing at 150 milliamps.

Switch-gear is provided to cut out the generator and connect the battery alone for low-power work, and also to cut out the filter when tonic-train is required, the note produced being very clear and of good pitch.

This plant, the circuit of which is shown in Fig. 3, is capable of delivering up to 100 milliamps. of perfectly smooth D.C. at 1,200–1,250 volts, and is largely responsible for the quality of the results obtained, no ripple whatever being traceable on the carrier up to full load and voltage fluctuations due to load-change being negligible—a most important point.

The next and highly important considera-

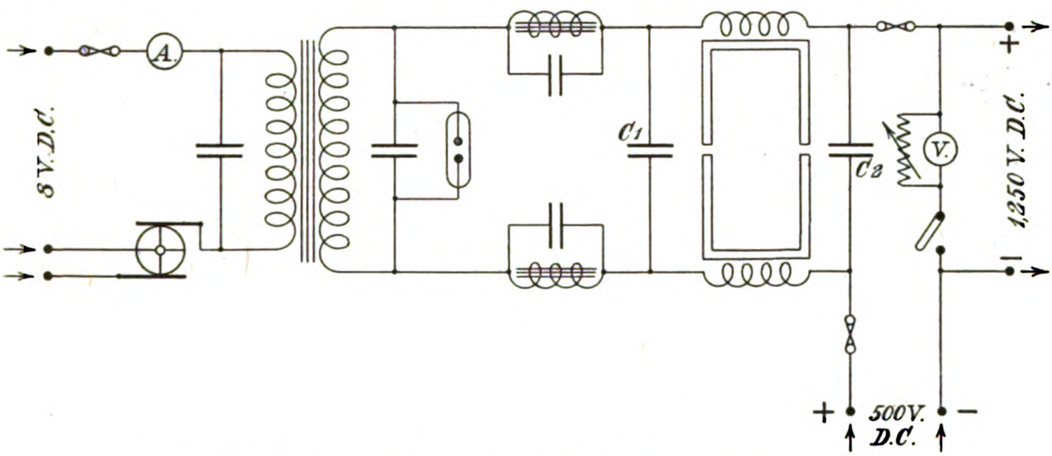


Fig. 3.—The generator and filter circuits. A milliameter, of course, is included in the main H.T. lead.

transformer C2, wound with 30 D.C.C., fluctuations across one winding of which give rise to equal surges of opposite polarity across the other, thereby strongly tending to neutralise any variations in the flow. The large condensers C1 and C2, of 4 mfd. each, were specially constructed to withstand an A.C. voltage of 3,000, and consist of 25-gauge sheet copper plates 12 ins. square in glass containers mounted on ribbed porcelain insulators, the dielectric being oil. Suitable means of discharging these when closing down are provided, as are also a glass-enclosed safety spark-gap across the secondary of the power transformer, set to flash at 1,000 volts, a fuse in the L.T. leads to the primary blowing at 2·5 amps. in the event of overload due to tion was that of control, it being necessary to modulate up to 80 watts or more with a minimum of distortion, and whilst little difficulty was presented by low powers of 10 watts or so with which choke-control could be used without too much wastefulness, this became a serious question where full power was concerned, as adequate control of a 100-watt transmitter by this system would necessitate the use of a 150-watt control valve with attendant increase in power consumption and expenditure. Grid-control, whilst economical, would not be suitable owing to the tendency to distortion and "spreading" of the carrier with this system, and after a series of experiments occupying a considerable time, in the course of which various systems and many permuta-

tions were brought into competition, choke-control was finally adopted for low power and absorption control for high, the chief trouble with this latter being, of course, harmonics. It is, however, a very economical system and capable of excellent results, the harmonic being actually avoidable, and grid absorption was ultimately adopted with complete success, although not often used with this type of oscillator.

To describe firstly the choke system—this is a fairly normal arrangement consisting of an iron-cored impedance specially wound to afford a flattish impedance peak at an R.M.S. speech-frequency in the neighbourhood of 800 p.p.s. at the input powers concerned, this somewhat low value allowing for the rather deep voice of the operator and the slight tendency of the resistance-coupled part of the amplifier to accentuate the higher frequencies. The choke is accordingly wound with 17,500 turns of 34 S.W.G. D.C.C. on an open core of soft iron wires, ·6 in. diameter, to an inductance value of 12 microhenries and a D.C. resistance of 850 ohms, the resonance curve being flattened by a non-inductive resistance of 100,000 ohms shunted across the winding, and the whole being sensibly aperiodic between wide extremes of speech and musical frequencies. It is connected in series with the anodes in the usual way, *via* two 0–50 milliammeters, as shown in the figures, control being exercised by an M.O./LS.2 valve in front of the amplifier, which will shortly be described. Control of grid-bias is effected in the manner described below.

The method of grid-absorption control used for full power is also shown in the figures, and will be seen to be quite normal, except that special means are adopted for correct adjustment of grid-bias on the control valve—a most important point—these taking the form of an iron-cored choke shunted by a non-inductive resistance of ·5 megohm, *via* which the necessary bias is applied from a battery tapped at each 1·5 volts, without appreciable leakage of the speech currents, the control valve itself being a Western Electric 208/A—a dull-emitting power amplifier of large emissivity, capable of full control of a 100-watt transmitter when used in this manner., A sensitive galvanometer in the grid-circuit of the control valves indicates the existence of any grid current in either case.

The speech amplifier used in both cases is now to be described, and consists of three valve stages coupled as shown in Fig. 4, the first two stages being resistance-coupled and the sub-control impedance-coupled, the stages being stepped progressively with regard to plate voltage, etc., to obtain correct and efficient operation of each. The voltage applied to the amplifier as a whole is 120, this being delivered to the valve plates *via* the resistances and choke of suitably apportioned resistance values, the capacity couplings being also apportioned so as to ensure maximum aperiodicity of amplification, the choke at the sub-control stage being suitably designed and shunted by a N.I. resistance of ·25 megohm to the same end, each valve being adjusted to the correct operation point by provision of suitable grid-leak and bias values, etc., care being exercised in the design to ensure avoidance of inter-circuital reaction effects at both high and low oscillation frequencies.

Dull-emitter valves are used throughout owing not only to considerations of current economy, but more particularly to the silence in operation of valves of this type—a most desirable feature when several stages of amplification are concerned, the valves used being AR-06 at the first stage, DER at the second, and B4 for sub-control, the mean amplification factor per stage working out at 6·2 and aggregating 240 for the whole. A tapping-plug allowing 'phones or L.S. to be plugged in provides for individual checking of amplifi ation and quality at each stage.

So large an amplifier for the modulation of 10—or even 100—watts may seem unnecessary, but it should be pointed out that the degree of magnification per stage has been purposely limited to a fairly low figure for the avoidance of distortion—amplification being in practice well sustained within extremes exceeding 300 and 3,000 p.p.s., and the amplifier being, in fact, practically distortionless—and that the microphone used is not of the carbon type, but is a special instrument of much less current displacement capacity, which will now be described.

This microphone is a magnetic instrument of not very usual type operating by a damped diaphragm vibrating in a permanent magnetic field, producing corresponding

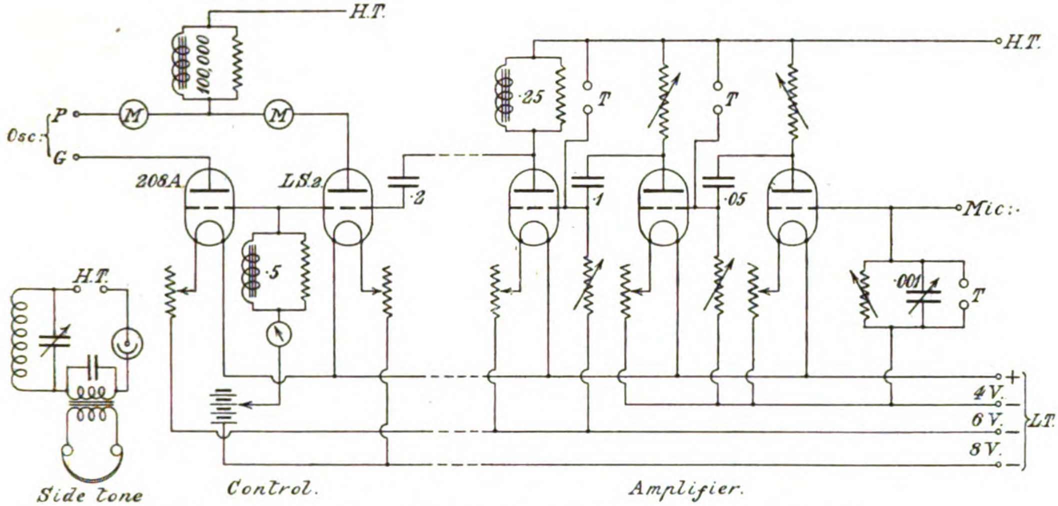


Fig. 4.—The special apparatus used in the distortionless amplification of the speech potentials.

current surges in field-coils wound therein, which are delivered direct to the amplifier. The coils are wound to a resistance of 4,000 ohms, and the field currents themselves operate the amplifier, there being no applied current other than the small negative grid-bias to the first valve thereof, which does not constitute a load proper but does operate in small degree to increase the field intensity and so also the sensitivity of the instrument. The diaphragm is of special construction, and is aperiodic between considerable limits of speech and musical frequencies, automatic compensation being provided in an effective and somewhat original manner, giving considerable freedom from distortion without undue loss of efficiency. The clearance between diaphragm and pole-pieces, which are collectively circular in shape to exert centre pull, is finely adjustable in operation by means of an external milled screw, input to the amplifier being adjustable by means of a continuously-variable resistance across the field-coils, *e.g.*, across grid and filament of the initial amplifier valve, across which is also shunted a variable float-condenser of ·001 mfd. maximum capacity to provide adjustable frequency compensation and absorption of sonic harmonics. The energy derived from an instrument of this type is, of course, considerably less than with a carbon microphone, and consequently requires greater amplification, but the results are infinitely superior if care be exercised in the design and adjustment of the amplifier, whilst the usual "packing" tendency is, of course, entirely absent. The principle of operation is shown in Fig. 5, in its simplest form.

The instrument described, which is the outcome of considerable experiment, is sensitive to speech at 6 ft. and to music at about double this, and is normally set to afford full control at about 18 ins., which is the working distance adopted in practice, no mouthpiece being used and the operator merely speaking towards it in normal tones, this considerably reducing the usual "blasting" tendency due not only to periodicity in the apparatus used, but to actual accentuation by the speaker of certain tones, to which, however accustomed the ear, the microphone is uneducated. The instrument itself is in the present case suspended by tensioned rubber straps in a frame mounted on a cushioned stand placed beside the operating bench for the avoidance of jars and mechanical vibration to which, though considerably less sensitive than a carbon microphone, the size of the amplifier renders it somewhat susceptible; and it is in this connection worthy of note that the valves of the amplifier are themselves cushioned and damped for the reduction of microphonic noises, which eliminates any tendency for the amplifier to "howl" from this cause.

This completes the description of the transmitting arrangements, and, whilst these

may be thought unnecessarily elaborate by those who may not yet seriously have attempted telephonic DX work, the writer would hasten to assure them that this is not so; and, whilst not for one moment suggesting the impossibility of covering long ranges with much simpler apparatus under favourable conditions, would urge that observance of the main considerations governing effective carry of a modulated wave and appropriate attention to the necessary details in the apparatus producing and receiving it must greatly facilitate the achievement of such results.

The receiver with which the station is equipped for short-wave DX is a six-stage "Ultradyne"—a new class of circuit developed by the writer of which space does not permit a description here; but the use of such a receiver is, of course, by no means essential, and adequate results should be obtainable with any normal arrangement of sufficient sensitivity if correctly designed and worked—a super-heterodyne receiver, for example, being particularly suitable and strongly to be recommended for short-wave DX. But whatever arrangement is used, it is essential that it be stable in operation, selective, highly sensitive, and as free as possible from distortion and internal noisiness, as these latter will render the most sensitive of receivers quite useless for really long-distance low-power telephony—in which connection it may be mentioned that, in the writer's case, not only are dull-emitter valves used throughout, but only one stage of audio-frequency amplification is used, and that is not transformer but impedance-coupled both as regards input to valve and output to 'phones, even this being frequently disused when QRM or QRN are at all in evidence, in which case a 15 ft. × 10 ft, indoor and a 6 ft. frame aerial are available and sometimes used.

It will be unnecessary to enter into remaining details of the station, except to state that all possible precautions against stray capacity effects are taken both within and without, the change-over switch, for example, which controls both receiver, transmitter and generator in a single operation and enables instantaneous changes to be made, whilst itself mounted in a convenient position on the operating bench, operates the aerial switch through a magnetic relay, the latter being mounted high above the bench close to the lead-in and well clear of all undesirable capacities and straying of leads, the same applying to the counterpoise lead, which is kept well away from the earth strip and all other trouble, the apparatus, etc., being so arranged that the length of high-frequency leads within the room is as short and direct as possible—actually a very few feet only.

This completes the description of the special means adopted in the quest of super-efficiency, and their effect is reflected in the practical results obtained, the working range of the station on a 10-watt input being of the order of 1,000 miles and telephonic communication having been established with places as far distant as Norway, Switzerland and Spain; whilst on 100 watts not only has an entire test transmission, sent out on telephony on the morning of December 13 last, when the transmitter was first tested on full power, been received at and fully reported from Boston, U.S.A., but two-way trans-Atlantic telephony was, on the morning of January 20 last, successfully established, it is believed, for the first time in history—though this is of less importance than the fact that its establishment on so low a power is thereby proved to be already possible by

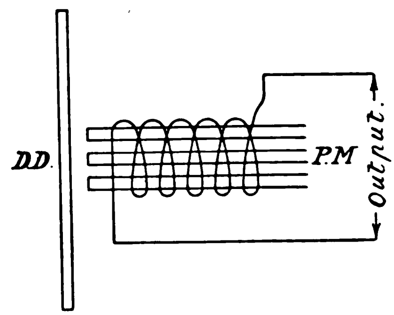


Fig. 5.—Illustrating the principle of the magnetic microphone.

quite standard methods and at small cost, furnishing additional evidence of the advance made in radio science during the last few years—one may even say months; and it is gratifying to note how much of this has come at the hands of amateurs, the achievement of British 2OD, for example, in establishing trans-Atlantic telegraphic communication on a power as low as 32 watts, being an epoch-making one in the history of the science, either amateur or professional.

Everything in the present case, with the exception of a few minor items, having been designed, constructed and installed by the writer single-handed and at strictly reasonable expense, it is hoped that this may, perhaps, encourage other amateurs to emulate on telephony the great things they have already done for radio on telegraphy; and in this connection the writer offers it as his considered opinion, formed as a result of considerable investigation of the subject, that reliable telephonic communication across the Atlantic is quite within the bounds of possibility on powers as low as 10 watts, and further ventures the prophecy, based on a knowledge of the ability and enterprise of the amateur experimenter, that such a result will, in fact, be achieved within a period of two years—by amateurs.

The Month's "DX."

Recorded by HUGH N. RYAN (5BV).

The increasing efficiency of amateur transmitters and receivers is resulting in the creation of many new long-distance records which are undoubtedly worthy of mention. It is proposed to record month by month work in this direction, and the Editor will be pleased to receive details for inclusion in these pages.

At the time of writing last month's notes we were still sufficiently in the thick of the first trans-Atlantic rush not to have had time completely to collect all the results which had been obtained, or to realise fully the extent of the good work which had been accomplished.

This being so, and conditions being now more settled, it may not be out of place here to give a *resumé* of trans-Atlantic work up to date.

Before the end of 1923 2KF, 2SH, 2OD, and 5BV had established two-way communication with the United States and Canada.

Since then the same result has been achieved by the following: 2SZ, 2NM, 2FU, 5NN, 5KO, 2KW, 2WJ.

The list of stations heard in the States during the official tests remains as given last month, since for some reason the R.S.G.B. appears to have dropped the subject and no further reports have been issued.

The results would, no doubt, have been even better but for the fact that from about January 26 until February 8 we had a spell of very bad conditions, during which trans-Atlantic work was practically impossible on any scale, though 2OD managed to keep up communication with Canadian 1BQ most of the time.

A number of additional American stations have entered the field of two-way working. Our old friend 1CMP, famous for his countless CQ calls on 200 metres, has now come down to the lower wave lengths. His programme at first consisted of further CQ calls, which many of our stations answered, without success. His reception has now greatly improved, however, and he now receives 2KF, 2OD, 2KW, and 5BV, having often effected two-way working. One wonders how many thousands of times 1CMP was called by British stations during the latter months of 1923 when his calls were such a familiar feature of the night watches! It is with a particular satisfaction that we connect with him after so many months of calling.

The distinction of being the American station heard best in England has kept changing from one to another. In the early days of two-way working 2AGB probably held the position. It then became the turn of 1XW. At present by far the strongest station I receive myself is 1XAM (Reinartz's Station), but 2KF finds 1BDI the best.

Many of us remember 1BDI as one of the star stations in the 1922 tests, and are glad to hear him again, especially as he can now hear our signals and reply!

In last month's notes I mentioned the large number of Americans worked by 2KF. He has not only maintained his lead, but

greatly increased it. Here is his list to date: 1XW, 1XAM, 1XAQ, 1CMP, 1BDI, 2AGB, 2AWS, 2CFB, 3XAO, 3OT, 8XAP, 9AZX, Canadians 1BQ and 3BP.

And the North used to say London couldn't work DX! 2KF's telephony has been received weakly by 1CMP, and strongly and clearly by 1BDI.

Dutch PCII is still working Americans regularly nearly every night. I am not sure how many he has worked, but the number is fairly high.

Another well-known Dutchman, PCTT, whom some of us had the pleasure of meeting in London recently, is now going again, and should get over soon. During the tests PCII and PCTT combined their apparatus to make one station at PCII.

Of the French stations, 8AB is still working, but is not heard so much as he was a month ago. 8CT, of Arcachon, who was heard in America during the tests, on 200 metres, has now reduced his wave-length, and is very strong indeed. The last time I heard him he was trying to connect with 1XAR, but I do not yet know whether he has been successful.

Some listeners on this side have been confused by the fact that some American stations on the short waves are apparently operated by men from different stations on 200 metres. The reason is that all American stations licensed for 100 metres are given a special call-sign for that wave-length, beginning with the letter "X."

Thus 1XW on 100 metres is the same station as 1MO on 200 metres. 1XAM is 1QP of 200 metres, and 1XAR is 1BDT of 200 metres.

Much more could be written about American work, which has become so absorbingly interesting to us all, but I think I have occupied enough space with it already.

In spite of the great interest in American work, much that is interesting is happening in European DX.

After becoming used to working the States, our stations have become so expert that European stations, which we worked with some difficulty two months ago, now seem quite "local."

It is interesting to look back, say, less than two years. In those days we were quite excited at working a French or Dutch station. An envied few could connect with 8AB, but most of us considered ourselves lucky if we were in the reports from Denmark, which were then just beginning to arrive. Our "testing" was usually carried out with a station a few miles away at most, and not until we had our sets tuned up to their very best did we venture to call a Frenchman. We now carry on most of our testing with Dutch or French stations, who are read with ease, and who can be "raised" with a single short call. Our only concern with the local stations with whom we used to do all our testing is now to tune them "out" instead of "in."

Italy, the latest country to possess amateur transmitting stations, is already doing very well. IMT (Venice) has worked a number of our stations. ACD, mentioned as an unknown station in last month's notes, is also in Italy (Bologna).

I believe he has, so far, only worked with two British stations (2KF, 5BV) and one Dane (7ZM), but he has received signals from a large number of British and French stations. He has also received telephony from 2KF.

One station (1JW) has started up in Luxembourg, and he has worked a number of British stations. I have received an enormous number of letters from British stations, saying that he was a new Italian station whom they had received! His signals are very strong everywhere in England.

The number of French stations has greatly increased recently. One of them, 8OH, is run by some soldiers in the French Army of Occupation at Wiesbaden. It is a useful station for testing the transmissions of those of our men who want to get further than Holland, but cannot reach Italy.

Now for what our own stations are doing. 5KO has been doing very well in trans-Atlantic work. He started a bit late, and is apparently trying to make up for it, with interest. He has, as far as I know, only worked one American (1XAR), but he has been received by a large number of them, including 3APV, Washington, and Canadian 9AL, Toronto.

5DN has worked XY (Geneva) again several times.

Mr. Niell, of Belfast, is still doing very well in reception. In addition to those mentioned last month, he has now received telephony from 2KT, 5DT, 2PX, 5IC, 5TR, 6NH, and 5BV.

5QV has worked French 8CJ on telephony, which 8CJ reported as being very clear.

M. Alphonse Boutié, of Ain Tedèles, Algiers, has received signals from a number of British stations. I have not the full list at present, but it includes 2JF, 5KO, 6RY, 2NM, and 5BV.

Now, just at the end, so that the shock you get on reading it won't matter, I will mention the ambition which is forming in the minds of several of our men, and that is direct transmission to Australia. It sounds pretty hopeless at first, but consider the facts. When we first started up on 200 metres it took us about a year to realise its possibilities, and nearly two years to do any useful DX. Yet within a month or so of "discovering" the shorter wave-lengths we are working regularly with Americans and Canadians, at ranges up to 5,000 miles. Then why, as we get more knowledge of the short waves, which we are rapidly doing, should we not increase the 5,000 miles to 12,000? 2KF and I have now met two of the Australian transmitters, and from their accounts it appears that they are blessed with splendid conditions. The foremost of their transmitters, Mr. McClurken, has worked with New Zealand, 1,100 miles, on 250 metres, with an input of ·004 of a watt!

If they can do that, then I prophecy that they will hear us within two years. But if European amateurs do get through to the Antipodes, let us see to it that the British stations do it first.

Apart from direct work, we are fixing up a relay to Australia through the United States and Honolulu. All the individual links in the chain are working, that between Honolulu and Australia being the weakest, and it is only a question of whether we can connect up before the season this side gets too late. We do not yet know whether we shall be able to keep up communication with America during the summer, but we hope for the best. After all, we first connected with France and Holland during winter months, but kept it up ever since, so why not America?

It is, at any rate, sure that we who are concerned with DX are having the most interesting time we have ever had before, or are likely to have again.

The Position of the High-Tension Battery.

A rough glance at a large number of receiving circuits will probably show that the negative end of the high-tension battery is as likely to be connected to the positive side of the filament as the negative side. When connection is made to the positive side of the filament the potential of the anode with respect to the negative end of the filament is certainly increased by about an additional five volts, but with an ordinary hard valve and a plentiful supply of high tension, there is no need to desire extra high tension from this source. There is, however, no objection to this practice in itself, but connection to the positive filament greatly endangers the life of one's valves if any experimental work is done. Whatever form of inter-valve coupling is employed there are always leads from the positive high tension and negative filament. In substituting another transformer, for example, or making any alteration whatever with loose wires, there seems to be nothing easier than to allow the positive high tension lead to come into contact with the negative filament.

Consider now the case in which the negative high tension is connected to the negative filament. The high-tension battery is merely short-circuited, which is indicated by a click and a flash. The battery suffers little damage. When connection is made to the positive side, however, conditions are very different. The battery is once more short-circuited, but this time through the filament battery. In other words, the full high tension is applied direct to a filament already near the point of fusion. There is little hope for the filament if the high-tension battery is at all new. The remedy is obvious—namely, connection to the negative filament. Of course, if in addition there is a lead from a grid leak to the positive filament one cannot then afford to be careless at all!

Dutch Amateur Transatlantic Tests.

By a Dutch Correspondent.

An examination of Dutch methods shows that the circuits employed, both for reception and transmission, vary considerably from our own. Below one of our Dutch correspondents summarises their work in the recent Transatlantic Tests.

DURING these trans-Atlantic tests, too, transmitting had not yet been permitted to the Dutch amateurs, and most of us were only allowed to listen for our English and French colleagues. Only to the Dutch station PA9 was an official licence awarded. This station belonged to the Technical High School at Delft, and had an input of 500 watts.

The amateurs who possessed a transmitter, however, did not mind this prohibition, and all risked trying to bridge over the ocean, except station oMX, who had a call after some days of testing of an official of the telegraph service and a detective. He was compelled to give up his A.R.R.L. testing, and only to listen for his colleagues, a very grievous thing for a thorough amateur.

Of the Dutch amateurs the stations PCII, PA9, PAR14, oDV, oAR and oYS were the principal transmitters, of which PCII, PA9, PAR14 and oDV had good results, while till this moment it is not yet known whether the stations oYS, oMX, oFN and oAR bridged the ocean or not.

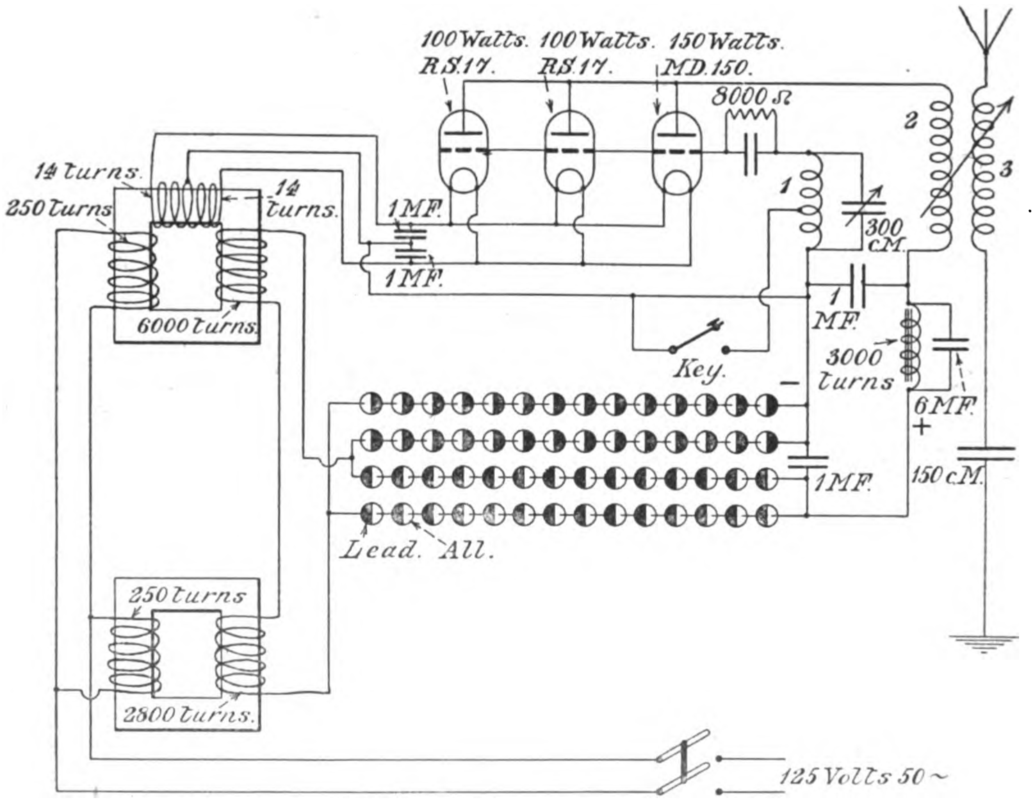


Fig. 1a.—The transmission circuit employed by PCII.

We will give now some descriptions of

some Dutch transmitting stations which got success, especially on a wave-length of 100–130 metres. Their attention having been drawn to results of French 8AB, which worked very successfully with American 1MO and 1XAM on 135 metres, and, after this, the success of English 2KF, the Dutch amateurs also lowered their wave-length from 200 metres to 100–130 metres, with the result that the most of them had less antenna current, but with the advantage that the well-known fading effect almost disappeared and that their radiation was better.

Station PCII was the first Dutch station on 112 metres, and succeeded in working with American 2AGB for two hours in the morning of December 28. In the beginning PCII worked on 200 metres with one 150-watt "Mullard" transmitting valve, with 3·5 amps. in aerial. After lowering his wave to 112 metres, the aerial current was only 1·6 amps. For all that, he was reported with this antenna energy. After this result PCII increased his transmitter by a second 1,500-volt transformer, and raised the solution of his electrolytic rectifier (ammon. phosph.) from 7 to 12 per cent. Parallel with the "Mullard" of 150 watts two 100-watt valves ("Telefunken") were placed so that the total input was about 350 watts, with 2,100 volts on the plate and 2·75 amps. in

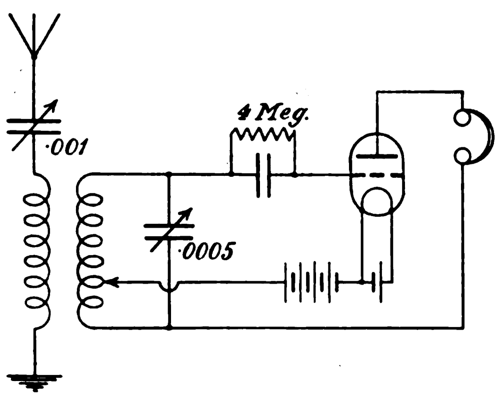


Fig. 1b.—Receiving circuit used by oAR.

aerial. The plate circuit is inductively coupled with the aerial; this was done to prevent variations of wave-length by swinging the antenna (Fig. 1a).

The aerial of PCII consists of four wires, 21 metres long, one end attached to a pole 21 metres high, the other end to the roof of his house. Below the aerial is a counterpoise of five fan-shaped spread wires, 4 metres above the ground.

On December 28, 0400 G.M.T., PCII got the first connection with 2AGB, who had

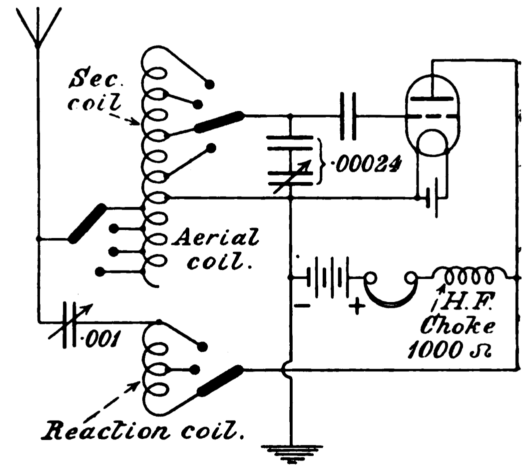


Fig. 2.—A modified form of Reinartz receiver.

900 watts input and 4 amps. aerial current. After some testing PCII delivered a message from the Dutch Radio Society, containing greetings to the A.R.R.L. The signals of 2AGB were strength 6 on one detector and a two-valve low-frequency amplifier. On December 29, 0450 G.M.T., 2AGB called PCII and gave qsa, but qrm qsu half hour cu half hour, 0533 G.M.T.; 2AGB gave still qrm, pse qsu few minutes more vy sri om. At 0550 G.M.T. 2AGB gave, after calling: qrm very bad, will come back to-morrow. At 0637 G.M.T. 2AGB called PCII: This is all right nw, qst fb. k. After this they had connection till 0715 G.M.T. On December 30 tests with C1BQ, but strength of signals too weak at break of day

Fig. 1a shows the transmitting circuit of PCII. Coil 1 is the grid coil, consisting of ten turns on a coil of 20 cm. size. It is not necessary to couple this grid-coil with the plate-coil.

Coil 2 is the plate-coil, nineteen turns on a coil of 18 cm. size, and coupled with the antenna-coil 1, of 3½ turns, wound on a coil of 13 cm. size. Keying is accomplished by shorting some of the grid-coil.

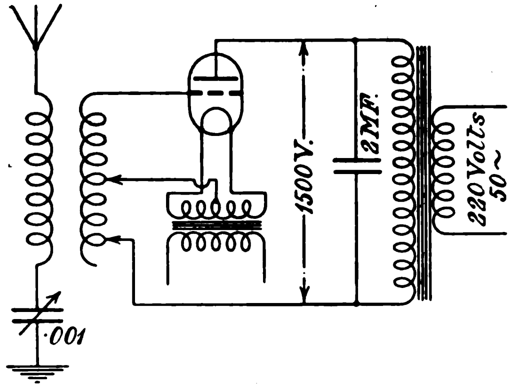


Fig. 3.—A very simple transmission circuit employed by oAR.

Receiver and Transmitter of 0AR (0XL).

Already during the month of November tests were done with several receiving and transmitting circuits to make comparisons and find the best.

First, the receiving circuit shown in Fig. 1b was used of French 8BV origin :—With only one detector the following American amateurs were heard: 1ANA, 1CDU, 1AW, 2BD (very qsa), 1BWJ, 2BSC, 1BCF, 8SZ, 1BLN, 1WL, 8CDC, 2BQH (qsa), 2WA, 8CKO, 3MO and 2CXL.

Generally, a counterpoise was used some metres above the roof. This slightly corrected the reception, because the local qrn decreased and at the same time a sharp aerial tuning was obtained. During the transatlantic tests a Reinartz receiver was mounted, with this difference—that the inductance was not a basket coil, but a common cylindrical coil (Fig. 2). The size and length of this coil is about 8 cm. The coil is vertically mounted in the set, and is wound with 3×15 turns for the plate circuit, 5×1 turns for the aerial, and 65 turns for the grid circuit, tapped at 16, 24, 34, 46 and 65 turns. The plate- and grid-coil are wound in two layers, the so-called "bank-wound." The wire used was litz wire, about 0·8 mm. size.

Maximum wave can be lowered by bridging the non-used part of the grid-coil, and as long as the bridged coil is not tuned on the wave on which one wishes to receive one will not be troubled by it.

The smoothing-coil is made of copper wire, 0·07 mm. size, and to a total resistance of about 1,000 ohms.

In series with the secondary condenser of 600 cm. a condenser of 400 cm. is placed, by which the maximum capacity of the

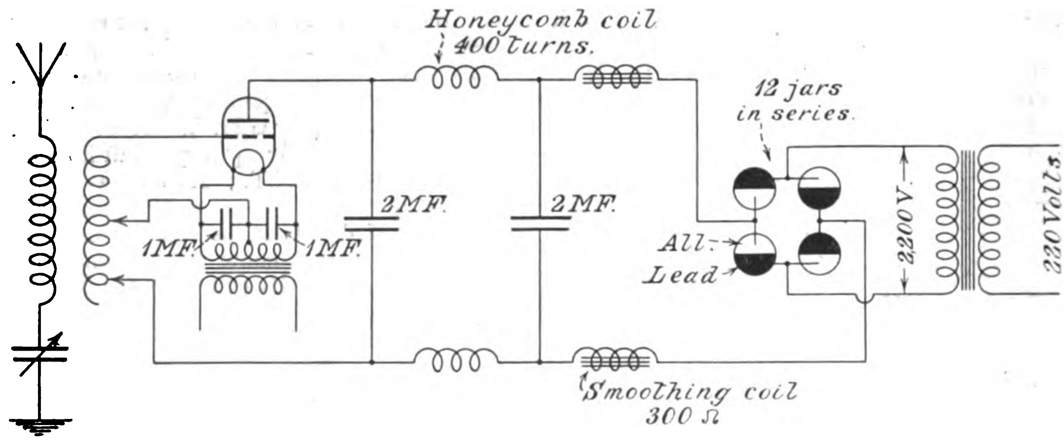


Fig. 4.—A modified form of Fig. 2 in which the supply is chemically rectified.

The primary coil of this circuit had twenty-four turns, while the secondary coil had forty turns litz wire wound on a coil of 8 cm. size. The strength of the signals with this circuit was very good, but tuning was difficult, as the aerial coupling had an influence on the oscillation of the valve.

secondary condenser is about 240 cm. This is of great importance for receiving very short wave-lengths.

With this receiver and one detector oAR heard the following American amateurs on the morning of December 2:—1BEP, 1XAM (on 100 metres very qsa), 2AWF, 8NB,

8CKN, 8CEI, 1CMP (calling French 8AB), 2RK (qsa), 1XM (on 100 metres very qsa), 2BD, 9VM and 9AN.

For transmission oAR (a combination of three amateurs) used the following circuit (Fig. 3). The primary coil had 25 turns, wound on a coil of 12 cm. size. The grid-coil had 25 turns, wound on the same coil of 12 cm. size. The high tension used for the plate was full alternating current, without any rectifying. With three 10–20-watt valves ("Telefunken") an aerial current was obtained of 2·5 amps. on a wave of 210 metres.

The note was very bad because of the terrible "hum" of the alternating current, so that oAR looked for a rectifying method. Some days before the trans-Atlantic tests the following corrections were made (Fig. 4): The primary coil and the grid-coil were changed into ebonite crosses, round which concentric hoop copper was wound. The two coils were fixed on hinges so that the exact coupling was easily found. The high tension of 1,500 volts was changed into 2,200 volts and rectified by an electrolytic rectifier (ammon. phosph. 10 per cent. solution), making use of the so-called "Grætsche circuit," to rectify the two phases of the alternative current.

Two high-frequency chokes were placed in the high-tension leads. The chokes were common honeycomb coils of 400 turns. By this the plate current decreased 50 milli-amperes. Condensers of 1 mfd., placed across the two halfs of the filament turns, made the note clearer.

After these corrections an aerial current of 2 amps. was obtained on a wave-length of 130 metres.

The aerial used was 20 metres long, 16 metres above the roof by means of two wooden masts. Below the aerial is a counter-poise of six wires, 25 metres long, 2 metres above the roof.

Transmitter and Receiver of oDV.

Fig. 5 shows the old transmitter of 5 watts, with which the first results were obtained. The high-tension transformer is on the table in a tin-lined iron box, filled with oil. Against the wall we see the unmounted 5-watt valve, the transmitting spider-web coils, and filament-plate and aerial-current ammeter. Near the transformer is the high-tension condenser of 2 mfd. The transmitter is visible mounted, as shown in the photo. All parts were made by himself, except the valves and ammeters. The antenna was a cage-aerial, 30 metres long and 16 metres high. A counterpoise was used of five wires and 50 metres long, which was used together with the common water-pipe earth.

Some days before the beginning of the tests the transmitter was fitted out with

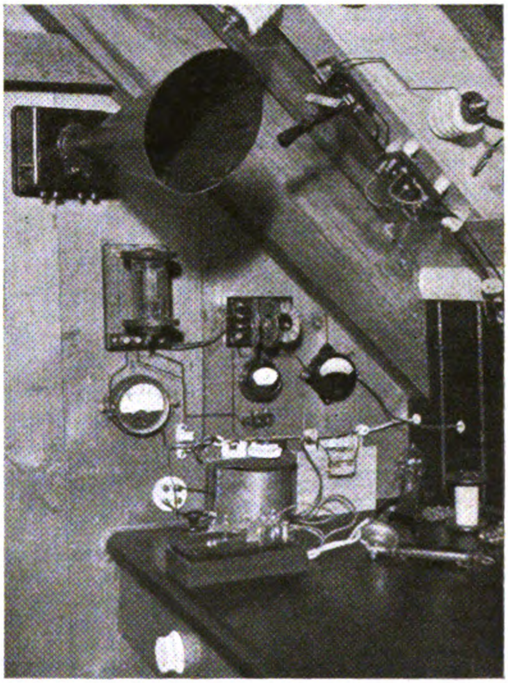


Fig. 5.—The original transmitter at oDV.

two 10–20-watt valves, and a new high-tension transformer was built.

To get a shorter way of his aerial to his transmitter the whole transmitter was removed to another corner of the room and was mounted there in haste, because it was one day before the tests (Fig. 6). To get the 100-metre wave the aerial must be shortened to a length of 12 metres and the counterpoise kept at a length of 50 metres. Especially the shortening of the aerial was accompanied with great trouble, in a very severe frost and snowstorm, during the A.R.R.L. days.

Fig. 6 shows the transmitter with which oDV bridged the ocean. To the right of

the photo, mounted against a chimney, is a ring-transformer, primary 220 volts, secondary 12 volts 10 amps. for filament of the transmitting valves and 2 volts 15 amps. for filament of a neon gas-rectifier valve. This valve is visible below the ring-transformer, and can be used for two-way rectifying, maximum 3,000 volts and 300 milliamps. Owing to this valve being so very short-lived (25 hours), oDV only used this neon valve for long-distance work.

Above the table we see the transmission coils and the filament ammeter, and on the table the two transmitting valves and a "Philips" rectifier valve of 100 milliamps.

Fig. 7 gives the transmitting circuit of oDV. The coils have been wound concentrically. Coil 1 has six turns and coil 2 has eight turns, both of 2·5 mm. wire size; coil 3 has twelve turns, wire size 1 mm. The capacity across coil 2 is about 0·0002 mfd. During the tests a radiation was

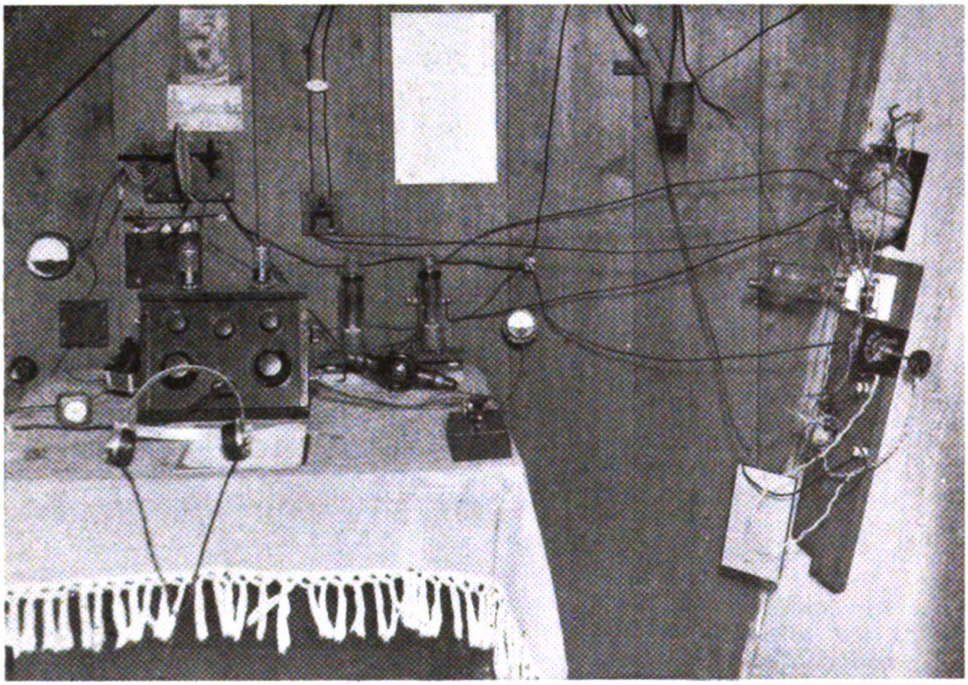


Fig. 6.—The rearranged transmitter at oDV which resulted in a much shorter aerial lead.

Below the neon valve is the "power switch," which varied the number of turns of the filament transformer in series with the high-tension transformer. This high-tension transformer is not visible in this photo, and is hung up in a wardrobe to deaden the buzzing of the transformer when it works with its full power. This transformer gives 2×2,300 volts, and is wound in segments, with wire of 0·3 mm. size. Below the "power switch" is a smoothing coil with a 2 mfd. high-tension condenser. Look at the other smoothing-coil, mounted in an old chocolate box and hanging up free above the floor!

obtained of 1·5–2 amps. on 110–130 metres, with an input of 200 watts. After some nights of testing oDV had the good fortune to be reported by 1KW.

In the beginning oDV had some hard luck with his high-tension condensers, and lost three of them. Being afraid that he would also lose his last one he decreased his high tension to 1,800 volts. Antenna current was then 1·4 amps. Also with this decreased power oDV was reported on other nights.

For receiving the circuit shown in Fig. 8 was used, with a reaction circuit like the "Reinartz."

The primary, secondary and reaction coils

are wound like spider-web coils, and are built in the set. The regulating of these coils is done at the side of the set. The primary coil has seven turns, secondary coil ten turns, and reaction coil has fifteen turns for reception of 80–250 metre waves. A two-grid valve, "Siemens-Schottky," with 12-volt plate tension, was used. Most American amateurs and American broadcasting stations were very good on one valve.

Finally, some news about station oYS. The same transmission circuit was used as described already in the November issue of EXPERIMENTAL WIRELESS, Fig. 8.

With two 10–20-watt valves and a common water-pipe earth he had an aerial current of 1·4 amps., while using a counterpoise and the same transmitter an aerial current of 2·5 amps. was obtained.

The aerial of 24 metres was too long—the lowest wave was 140 metres—but there was no time before the tests to shorten his aerial. Till this moment there has been no report as to whether oYS had any results with his testing.

For receiving a kind of "Reinartz" receiver was used (Fig. 9). The inductance is wound in one piece, with one tap about in the middle. No special manner was used to wind this inductance. The turns are laid in a small hollow wooden plank, 60×65 mm. The hollow is covered by means of a second little plank.

For waves of 100–250 metres the best result was obtained when about eight turns were used for the part *a* and about fifteen turns for the part *b*.

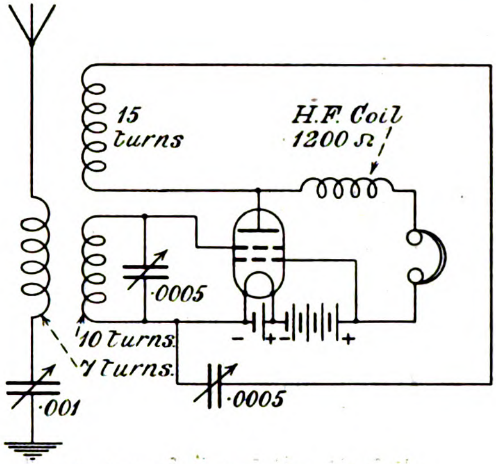


Fig. 8—A four electrode valve receiving set.

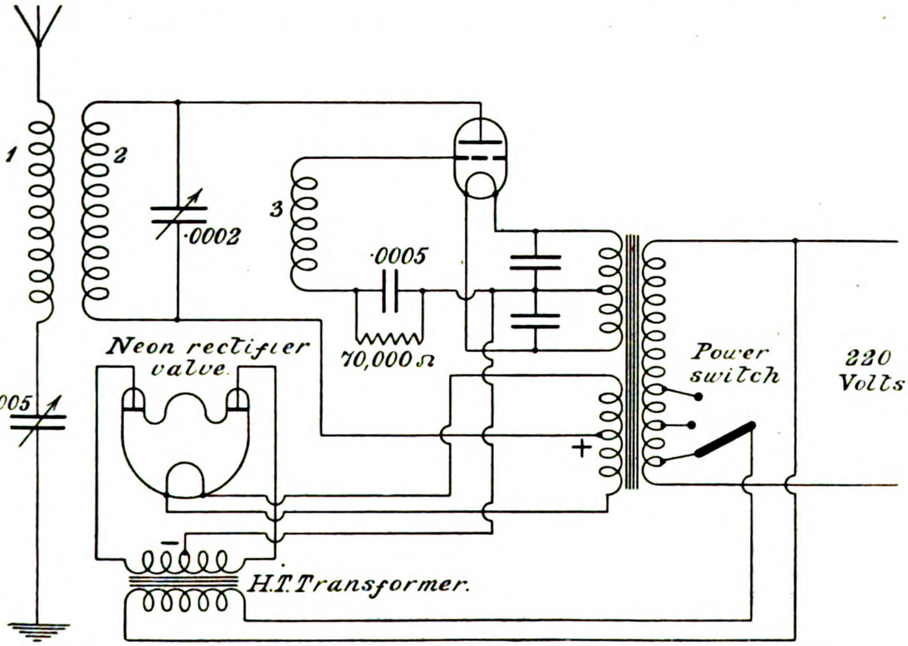


Fig. 7.—The supply to the anode at oDV was rectified by a special neon tube as shown above.

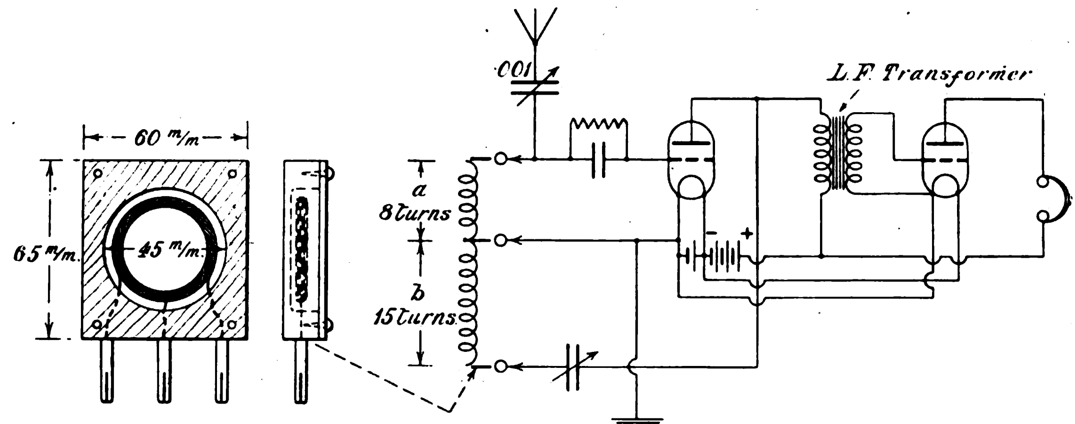


Fig. 9—The receiving circuit used by oYS was another modified form of Reinartz receiver with one stage of low frequency amplification.

As we see, most Dutch amateurs use their own transmission and receiving circuit, and seldom do we use exactly the same as those of other amateurs.

When we look back to the past days of testing we may be very content with the results which several Dutch amateurs obtained.

American 1MO.

By K. B. WARNER.

A brief description of the first American station to bridge the Atlantic on 100 metres.

THIS transmitter is operated by our traffic manager, F. H. Schnell, under the call 1MO, and by myself under the call 1BHW. It is licensed for the shorter wave work, however, only under the call 1MO, under which it has been operated by both Mr. Schnell and myself. The set was built by Mr. Schnell in accordance with the suggestions of Mr. John L. Reinartz, of 1QP and 1XAM. The particular virtue of the circuit lies in its ability to shift rapidly wavelengths, and yet maintain the node in a fixed position.

Briefly described, the circuit is a full-wave self-rectifying circuit, with two UV203A tubes on each half of the cycle. Whatever unusual merit it may possess as a transmitting arrangement probably lies in its ability to work well below the fundamental of the antenna, in the region where the radiation resistance is relatively enormous. For example, the antenna current on 200 metres is in the neighbourhood of 6 amperes, at 115 metres it is about 2¼ amperes; these figures with an input to the plates of approximately 400 watts.

Mr. Leon Deloy, of French 8AB, has long been a personal friend of Mr. Schnell's. Deloy was in this country this summer, studying amateur methods, and decided to employ this Reinartz transmitting arrangement. Returning home, he installed it, and upon completion wired the traffic manager that he would start transmitting on the Sunday night before Thanksgiving. Schnell hurriedly wound a few coils for a crudely made short wave receiver of the tickler feedback type, and was listening on 100 metres at the appointed time. Deloy was received quite splendidly—with two-step audio amplifier

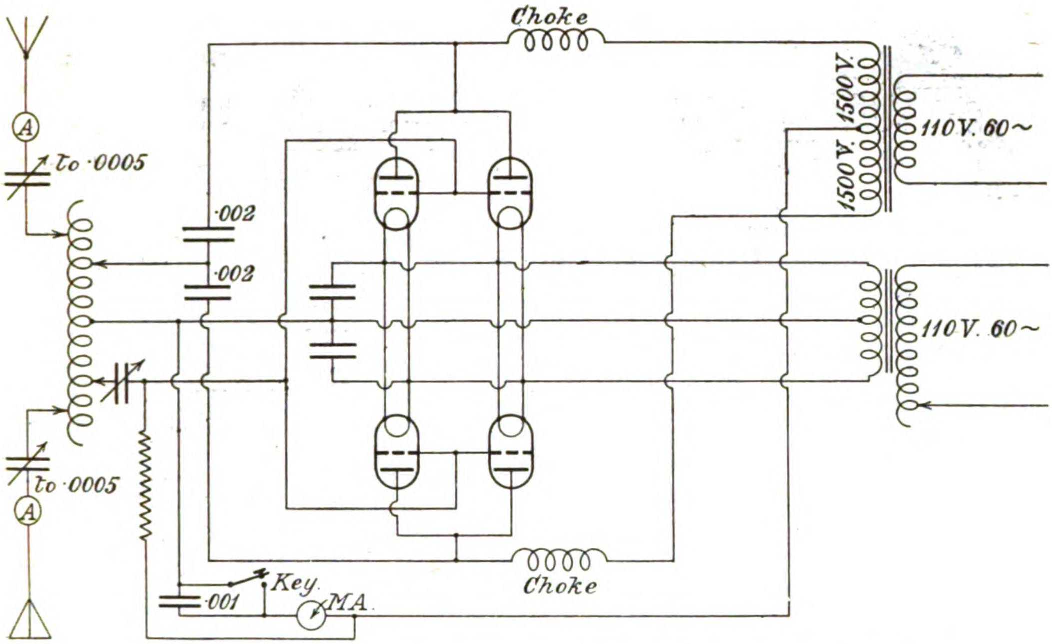


Fig. 1.—The circuit used at 1MO is a full-wave self-rectifying circuit employing UV203A valves in parallel.

his signals could be heard 25 feet from a phonograph horn carrying an ordinary telephone. His broadcasts were copied on the nights of November 25 and 26. By the night of November 27 Mr. Schnell had secured permission from the Radio Supervisor to use the wave-length of 115 metres, and upon the conclusion of Deloy's broadcast that night he called him and communication was established. Since then it has been accepted as a matter of course. Deloy is worked almost every night, and probably a dozen American stations have connected with him. His signals have been heard far inland, and with very good audibility. On the night of December 7, at the conclusion of our regular schedule with French 8AB, he assisted in connecting me with British 2KF, of London, whom I worked for a matter of several hours, stopping only at 8.40 British time when the signals of 2KF finally faded out here. I have worked 2KF a total of five times. On the night of December 11, at the conclusion of correspondence with him, he asked me to listen for British 2SH, our mutual friend Hogg, and I am happy to say that I connected up with him, too, for a period of about two hours and ten minutes. I had a schedule with him later in the week, but unfortunately

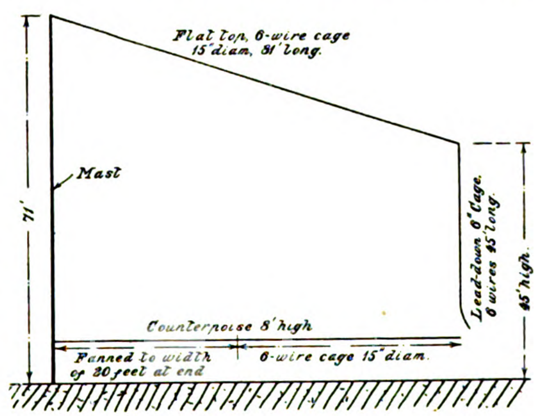


Fig. 2.—The aerial and counterpoise system at 1MO.

could not hear him. On the night of December 15, at the conclusion of correspondence with French 8AB, he connected me up with French 8BF, our fourth European correspondent, with whom I talked for over half an hour.

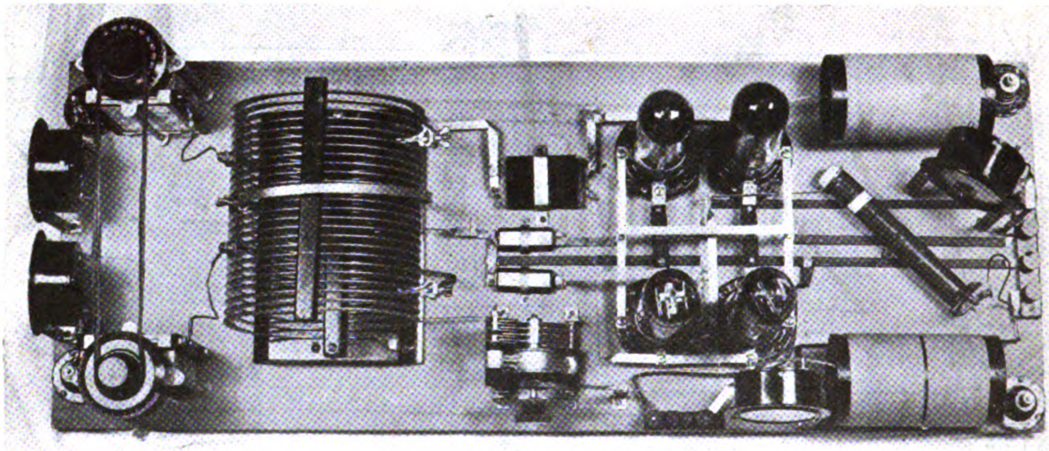


Fig. 3.—Showing the layout of the apparatus. Note the two condensers linked together by a belt so as to enable the aerial and counterpoise circuits to be adjusted simultaneously.

Modern Methods of Production.

SOME IMPRESSIONS OF THE STERLING WORKS.

IT was with very great interest that we accepted the invitation of Mr. Guy Burney, Managing Director of the Sterling Telephone & Electric Co., Ltd., to visit their extensive works at Dagenham, where we were able to obtain some insight into modern methods of mass production. Apart from technical points, we could not help being impressed by the elaborate and splendid organisation which prevails throughout the whole works. The factory is certainly run under model conditions, and the amount of consideration which is devoted to the welfare of the workers is, no doubt, largely responsible for the atmosphere of goodwill which seemed to prevail wherever we went.

Statistics are of little use in giving the reader an accurate impression of the size of the factory, but some idea of its extent can be obtained from the fact that the power house comprises six 200-kilowatt units. These, it may be mentioned, are driven by Browett-Lindley gas engines, which derive their power from a suction gas producer system installed nearby. We were told that the fourteen hundred kilowatts which are available are scarcely sufficient to maintain the whole works in operation. It is interesting to note that although alternating current is becoming almost universal, in this instance direct current is used on account of its greater flexibility for purposes for which it is required.

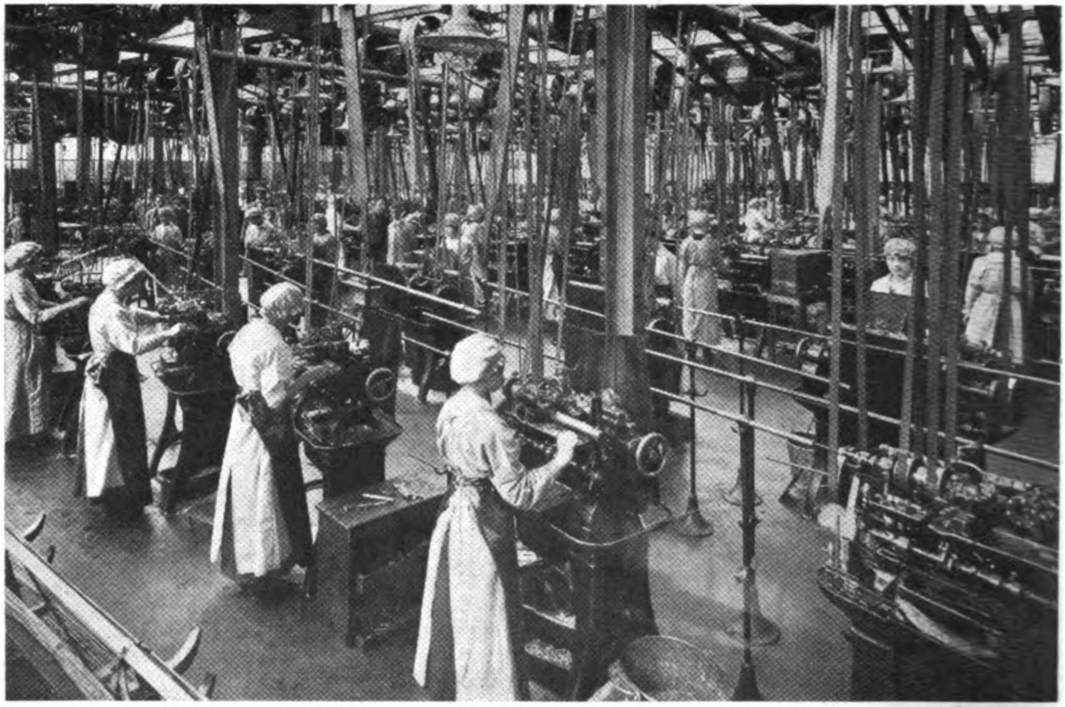
It will, no doubt, be remembered that the greater portion of the Sterling Works is devoted to the manufacture of Post Office telephone apparatus and wireless receiving gear, which necessitates the use of wooden cabinets. This great demand for cabinet work has brought into existence a special department, and perhaps the methods employed will be of some interest to our readers. Until recently there had been considerable difficulty in securing the large amount of really well-seasoned timber which has been necessary. However, this difficulty has been overcome by the installation of what we may best term a seasoning plant. A series of drying kilns are used, in which the timber is placed for some three weeks under accurate temperature and humidity control. The timber is then removed and it is accurately analysed for moisture content, and having passed the test satisfactorily, it is then ready to be sent to the cabinet shops. The cabinet

shops themselves are very completely equipped with very up-to-date machinery, great use being made of sand-papering machines. The sand-papering machine, we understand, is extremely economical in working, and, moreover, gives an extremely fine surface to the wood. It is particularly interesting to note that all the driving machinery is concealed in tunnelling under the floor, several machines being grouped together and driven by one electric motor. We were told that considerable difficulty was experienced when the system was installed, owing to the fact that the proximity of the works to the river resulted in standing water being very near the surface of the ground. This necessitated the construction of special channels for the driving machinery, and we were told that they were formed of puddled clay, heavy concrete, asphalte, brickwork and cement. The atmosphere of a cabinet shop is usually associated with vast quantities of sawdust, shavings, etc., but in this instance none was present owing to the fact that a very elaborate system of suction ventilation is employed.

Some idea of the extent of the Sterling works can be gathered from this view of their own tool shop.

The methods used in finishing the wood are equally as ingenious as those used in working it. Unfortunately, we are not at liberty to give any details of the methods used, but we may go so far as to say that they are entirely different from those usually adopted in polishing. The wood is first treated with a special filler, and is subsequently mechanically coated with a special varnish which can either be made to have a high polish, or, alternatively, a streaky dull appearance of wax-polished timber. The advantage of this method results in a saving in time, a lower cost of production, and a finish to the wood which is quite waterproof, a feature which should be of great advantage in electrical apparatus.

Usually the assembly of finished cabinet work and the fitting of the instruments needs considerable care and adjustment, but Mr. Max Lawrence, the distinguished works manager, who accompanied us throughout out tour of inspection, informed us that the cabinet work has been standardised so successfully



A busy corner of a machine shop. Note the battery of automatics in the foreground.

and the timber so accurately seasoned, that everything is always in perfect register.

Roughly speaking, the output of the Sterling Works can be divided into two classes—telephone apparatus, which is under the charge of Mr. F. R. Griffiths, and broadcasting apparatus which has been designed entirely by Mr. D. Ward Miller, who, no doubt, is well known to many of our readers. The instruments are made so many and various that in the short space available it is quite impossible to deal with each adequately, and, therefore, we cannot do better than generalise, dealing more fully with points of special interest. Perhaps one of the most interesting departments is that in which the well-known Sterling high-resistance telephones are wound. Special precautions are taken to protect the telephones from all injurious influences, especially from the effects of damp, and this is no easy task in view of the fact that some 20,000 turns of wire are used in each pair of telephones, which, of course, means that an exceedingly fine gauge has to be employed. The wire, as a matter of fact, is enamelled copper of about 1-1,000th inch in diameter. Transformer coils receive equal care, and before they are wound the reels of silk-covered wire are impregnated *in vacuo* with hot paraffin wax, which results in a coil of greater mechanical and electrical strength. Reverting to the subject of telephones, we were particularly interested in the production of the magnets, great care being taken to bring the high-quality tungsten steel into the best electrical and mechanical condition. The distance between the diaphragm and the magnet is of considerable importance, and when the magnets have been assembled within the cases, the receiver is placed on a machine, which grinds down the magnet poles until they are of exactly the correct length. The manufacture of loud speakers is another process worthy of mention. The movement of the loud speaker, of course, is very similar to that employed in the ordinary headphone, but the horn embodies several interesting features. The flare is spun out of aluminium in the usual way, but the throat is made of two brass pressings brazed together at the edges. The join is subsequently examined to ensure that

it is faultless. The throat is then tin-plated before it is passed to the finishing shops. No doubt many of our readers are familiar with the decorative Sterling loud speakers. The finish is secured by means of stencils and air brushes, and although the process may appear as being almost mechanical, it undoubtedly depends very largely upon the artistic individuality of the operator. Here, again, the enamels, etc., are of a special type, and are worked in a somewhat similar manner to the varnishes used in the cabinet shops.

Sterling broadcast receivers are too well known to call for comment, but it is interesting to note that the complete receiver is made in the form of a unit which slides into the cabinet. The black-finished brass front panels are certainly novel, and have many points in their favour. In addition to elaborate testing, each instrument is examined on broadcast signals before being finally passed.

To the mechanical engineer, no doubt, the most interesting section of the works would be the gigantic main machine shop, which is literally crammed with automatics, and a tremendous amount of turret work is done here. The other section of the building is devoted to press work, which plays no small part in the Sterling productions. It is a matter of some regret that we are not at liberty to make known to our readers some of the most interesting points in the production of Sterling apparatus, but we can assure them that a higher standard of workmanship and quality would be hard to find, and we are very greatly indebted to Mr. Guy Burney for the opportunity he has afforded us for examining modern methods of production.

One of the cabinet shops in which the artificial ventilation installation is clearly visible.

The Trend of Invention.

We summarise below the more important wireless inventions which have been disclosed during the month, special reference being made to those of immediate interest to the experimenter.

Microphone Design.

New types or designs of microphone are always of interest—especially to the radio man who has at heart the improvement of radio-telephony. Fig. 1 shows a recently patented mode of construction for carbon

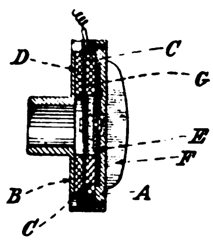


Fig. 1.—A new type of carbon microphone.

granule microphones, which rather appeals to us. The chief object of this invention is to support the moving diaphragm entirely by felt, or similar substance, and avoid rigid contact with the metallic case, thus making the microphone practically aperiodic in response, and avoiding the resonance which is so predominant in most commercial microphones. Fixed to the back A of the case is a metallic disc E, faced with the usual carbon disc, which forms the back electrode of the granule chamber. In front of this disc is a disc C of felt with a hole cut in its middle to form the granule chamber. Placed in front of this felt disc so as to close the granule chamber is the diaphragm G, which is held in position by the felt disc C and a second similar felt disc D. Thus, when the front plate B of the microphone is screwed in position sufficient pressure is exerted to hold the diaphragm securely in place. The inventor prefers to cut the hole in the felt discs to an oblong or elliptical shape, with the major axis horizontal. The diaphragm itself is of such a thickness that it moves as a whole and not only at its centre. Connection is made to the diaphragm by a thin strip of metal. The back of the case is provided with radiation fins so that the microphone may be used with comparatively large currents for prolonged periods without undue overheating. (British Patent 209,173, E. A. GRAHAM).

High-Speed Morse Recorder.

Fig. 2 illustrates British Patent No. 190,113 (Marconi's W.T. Co., Ltd.), the chief point of interest in this invention being the means whereby small currents directly control the movements of the marking stylus. A polarising winding C is energised by a local source of current, the case A, the core B, and top plate E all being made of iron, and forming a magnetic circuit which is closed except for a small annular air gap round the top of the central core B. An intense magnetic field is thus formed in the annular air gap, and in it is suspended a light ring-shaped coil of fine insulated wire, shown in section at D. This coil may contain 500 to 1,000 turns of wire, and is suspended from the light aluminium arm F, which is capable of oscillation in a vertical plane, and whose free extremity carries an inking stylus which makes the

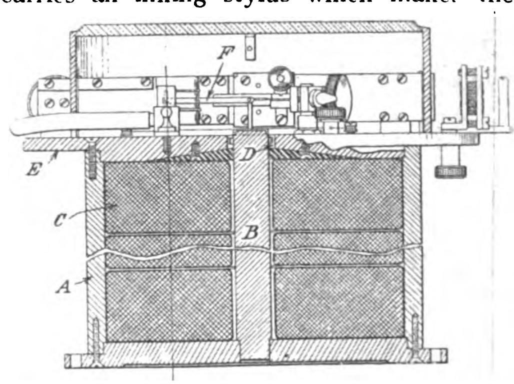
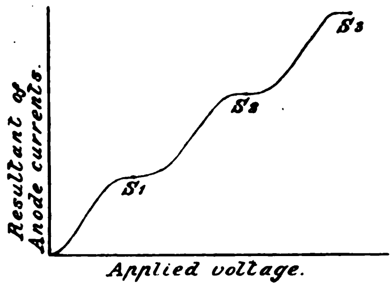


Fig. 2.—A high-speed Morse recorder working on a principle somewhat similar to that of the "Magnavox" loud speaker.

record on the moving tape. Signalling currents are fed into the suspended coil D, and, owing to the strength of the polarising field, quite small currents in D will result in a strong solenoidal force which actuates the recording arm F. The principle on which the electro-magnetic system of this invention acts appears to be identical with that used in the



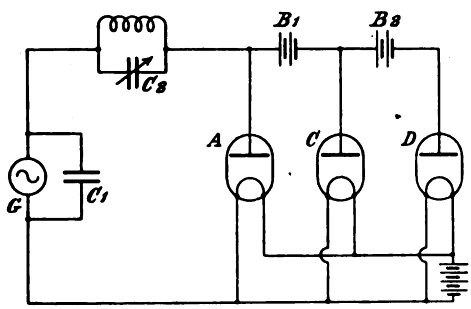


Fig. 3.—Another circuit for frequency multiplication.

Magnavox loud speaker, the only novelty lying in its application to Morse recording. Full details of mechanical construction, which we cannot reproduce here, are given in the specification referred to.

Valves as Frequency Multipliers.

Most static devices for raising the frequency of an A.C. source depend on using some saturation or threshold effects to distort a sine wave in such a way as to be resolvable into some multiple frequency or frequencies. The most practicable devices hitherto devised have depended upon the magnetic saturation of iron or its alloys. British Patent 208,735 (J. Scott-Taggart and Radio Communication Co., Ltd.) suggests a method of utilising the properties of thermionic valves for frequency multiplication, or effecting any desired change in wave-form. Fig. 3 illustrates the broad idea of the invention simply. In series with the source G are a number of two-electrode valves A, C and D (and more if wanted) in multiple connection across G. By means of batteries B_1 and B_2, the anodes of C and D are given suitable negative biases, so that the anode of C is more negative than that of A, and that of D is more negative than that of C. Now consider what may happen when the positive half-cycle of e.m.f. is generated by G. A will at once begin to conduct, but C and D will not, owing to their negative biases. The current through A will increase until saturation current is reached; there will then be no further rise in current until the positive e.m.f. of the source G has risen sufficiently to overcome the back e.m.f. of the battery B. When this happens C will begin to conduct until it is saturated, and again a further increase of current will be delayed until the back e.m.f. of B_2 is overcome. The curve in Fig. 3 shows the state of affairs in the first part of the positive half-cycle, the same things happening in the reverse order in the second part of the positive half-cycle (not shown). The result of so distorting the positive half-cycle is the production of a strong harmonic component, which may be selected by a circuit LC_2 included in series with the source G, and tuned to the said harmonic frequency.

The specification describes modifications of the invention, including the extension of the idea to three-electrode valves, in which latter case the grids are successively biassed and the harmonic frequency is delivered in the common anode circuit.

Ingenious as this invention is, it has a serious fallacy, which will, no doubt, occur to

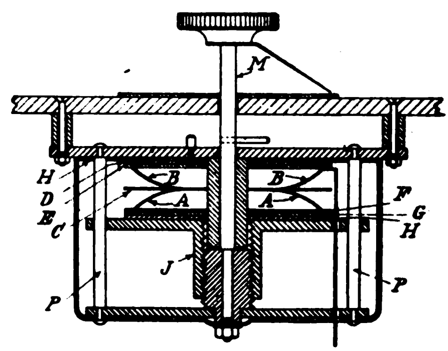


Fig. 4.—A variable condenser of the well-known "Polar" type.

some of our readers, namely, that since thermionic valves only conduct one way, the devices will only act on the positive half-cycles, there being no output on the negative halves. Hence the output will be completely interrupted each cycle for a period lasting half a cycle—resulting in the production of an infinite series of harmonics.

Variable Condensers.

Fig. 4 illustrates the construction of a condenser of the type of the now familiar "Polar." The condenser plates, of which there are only two, consist of sheets D and G of copper foil mounted on sheets of press-pahn, or similar resilient material, marked

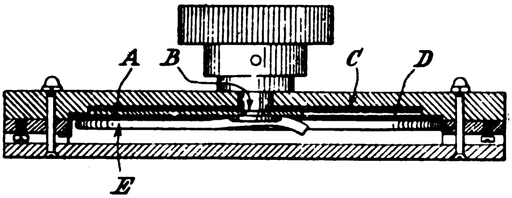


Fig. 5.—A "mica lubricated" condenser.

H. Sheets of mica E and F prevent the plates being short-circuited. The condenser plates are always kept parallel and are urged apart by means of tongues A and B, bent out from the springy metal sheet AB. By rotating the knob attached to the spindle M the support J of the lower plate is urged towards or away from the upper one by virtue of the screw-thread in J. The guide bars P prevent J from rotating. (British Patent 208,598, F. K. Crowther and Radio Communication Co., Ltd.)

Another method of making a compact variable condenser is illustrated in Fig. 5. (W. Dubilier, British Patent 201,138.) Fixed and moving vanes similar to the ordinary type are used, but all the plates are kept pressed together, the necessary dielectric separation being entirely effected by thin sheets of mica. The moving vane A is a brass semi-circular vane about four or five mils thick, and connected rigidly to the spindle B. The fixed vanes C and D are also of metal foil, and are separated from the moving vane A by mica discs. All the vanes and mica discs are kept pressed together by the spring wire retainer E. The specification covers the use of this arrangement with a plurality of moving vanes as well as only one as illustrated. It is stated that owing to the small co-efficient of friction of a mica surface that the arrangement works better than similar types of condensers employing hard rubber or ebonite dielectric. Apparently after a certain amount of use a very fine mica dust forms between the rubbing surfaces which has a lubricating action.

Self-Capacity in L.F. Transformers.

Many of our readers may wonder at the rather unusual dimensions of the Western Electric Co.'s speech amplifying transformers. The plan of such a transformer is shown in Fig. 6, which illustrates the large diameter of the bobbin A compared with its width. The object of this proportioning is to reduce the self-capacity of the windings, and thereby to increase the transformer efficiency on the higher speech frequencies. By making the windings on a narrow bobbin and making up for the otherwise consequent loss of accommodation by increasing the diameter, it is obvious that the separation between the inner and outer turns will be increased, and the self-capacity decreased. (British Patent 209,345, Western Electric Co., Ltd., C. P. Smith, and W. L. McPherson.)

Iron Alloy for Iron Cored H.F. Circuits.

In the early days of radio it was thought that it would not be practicable to use iron-cored coils for H.F. work owing to the high hysteresis and eddy-current losses—especially the latter. Later it was found that a reasonable efficiency could be obtained provided that the iron was very well laminated, and suitable insulation effected between the laminations. Also the eddy currents can be minimised by using iron alloys of high resistivity, and such alloys should also have a low hysteresis loss. The composition of an

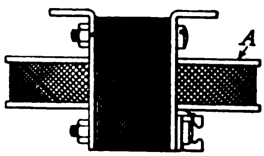


Fig. 6.—The bobbin of the Western Electric Transformer is of the shape shown above in order to decrease the self-capacity.

alloy to meet these requirements has recently been patented by Marius Latour (British Patent 209,683). This alloy contains 33 to 39 per cent. of nickel, and 0·5 to 1 per cent. of manganese.

Loud Speakers and the Institution of Electrical Engineers.

In our issue of January last we published abstracts of two of the papers read on November 29, 1923, at the Institution of Electrical Engineers, the occasion being a joint meeting with the Physical Society of London. The meeting remarkably demonstrated the great interest taken in the subject of, and the large amount of experimental work which has been and is being done in connection with, "loud speakers," and the scope this part of wireless apparatus alone offers to experimenters. So large was the attendance that the lecture theatre was crowded to the doors, many members went away having been unable to obtain admittance. Dr. Eccles, speaking in the discussion, remarked that the "loud speaker" had brought about a new era in which one man can address thousands. One of the difficulties in evolving a loud speaker was that it must be able to cope with a wide range of vibrations. An audience came either because they were interested in or liked music, because they wanted to hear broadcasting, or because they were scientifically interested. Referring to the experiments and success obtained by the Western Electric Laboratories, he said if you are near the loud speaker the sound seems too loud, if far away it is too faint for ordinary conversation, if you are at the right distance you would say it was the actual voice of the speaker. Oscillograph curves taken from a gramophone speaker indicated the difficulties. He estimated loud speaker efficiency as only one tenth of one per cent. The discussion, as a whole, indicated that there are great difficulties in the way of evolving a loud speaker which will serve perfectly under all conditions. Acoustics enter largely into the matter, the size and the sound conditions of the place in which a given loud speaker may be used. An instrument which gives satisfactory results in a large hall may be unsatisfactory in a room or even in another hall. One remark was to the effect that horns for use in small rooms should be short rather than long. Makers of gramophones have had to deal with similar difficulties. A variety of demonstrations with loud speakers was given during the evening. Mr. Sandeman had made experiments, and showed curves demonstrating the effects of filtering out frequencies below 1,500 and above 1,500, and of admitting both; they indicated that distortion occurred with frequencies above or below 1,500. Professor MacGregor Morris gave a very interesting demonstration of his experiments to discover overtones in the diaphragm of a telephone receiver. They are based upon Chladni's experiments in which sand placed upon a metal plate distributes into lines and curves depending upon the vibrations imparted to the plate. The discussion was resumed on February 14. It demonstrated further that loud speakers are a very complex problem, not only affected by design of apparatus, but having to meet actual defects of sound reception in the human ear itself. Mr. A. J. Aldridge showed some curves illustrating comparative output and input of a diaphragm with a given input of energy. There were more demonstrations with apparatus, one being with two loud speakers, the horn of one delivering into the horn of the other. Apparently the resonance of the horn itself is of small consequence, because the horn magnifies so greatly the happenings which occur in the apparatus connected to it. Mr. Burnand described experiments he had made with two loud speakers in series. Sometimes one and sometimes the other appeared to take charge of the sound delivery. He suggests two horns combined, and humorously remarked that there is a great opportunity for an experimenter to be shut up in a room with a plentiful supply of horns and paraffin wax. This remark amused the audience; also his further observation that he had personally worked out about 9,000 windings. The position was tersely summed up by another member in the following observation:—"The weakest link in broadcasting is the receiver, and the weakest link in the receiver is the loud speaker." From our point of view the papers and discussion are an object lesson to experimenters, showing that useful and important work can be done by devoting attention to a single detail where improvement and development may be needed.

Recent Wireless Publications.

Figures after the title of each publication indicate Volume and Number of Publication containing the article. Where only one number is given, this indicates the serial number of the publication. The abbreviations used in this bibliography will be found in the early issues of "Experimental Wireless."

I.—TRANSMISSION.

UNE ANTENNE D'EMISSION POUR AMATEURS.—P. Bouvier (*R. Elec.*, 5, 52).

UBER DIE ABHÄNGIGKEIT DER FREQUENZ DES RÖHRENSENDERS VON DER HEIZUNG DER RÖHRE UND DER ANODENSPANNUNG.—Felix Strecker. (*Jahrb. d. drahtl. Tel.*, 22, 6).

THE D.C. VOLTAGE RAISER.—Marcus G. Scroggie, B.Sc. (*Exp. W.*, I, 5).

THE IMPROVED "S" TUBE RECTIFIER.—James L. Jenks, Jr. (*Q.S.T.*, 7, 7).

SOME CHARACTERISTICS OF ELECTROLYTIC RECTIFIERS.—E. J. Atkinson (*Q.S.T.*, 7, 7).

II.—RECEPTION.

LOUD SPEAKERS.—E. K. Sandeman (*W. World*, 232 and 233).

ELECTROLYTIC DETECTORS AND LIQUID VALVES. —James Strachan (*W. World*, 232).

A FOUR-VALVE DUAL NEUTRODYNE RECEIVER. —W. James (*W. World*, 233 and 234).

LE MEILLEUR RÉCEPTEUR POUR TOUTES LONGEURS D'ONDE (80 À 25,000 MÈTRES).—J. Reyt (*R. Elec.*, 5, 53).

MESURE DE LA PUISSANCE DE RÉCEPTION.—J. Roussel (*R. Elec.*, 5, 53).

DESIGN FOR A DUO-REGENERATIVE RECEIVER.—Capt. St. Clair-Finlay, B.Sc. (*Exp. W.*, 1, 5).

LOW LOSS TUNERS.—S. Kruse (*Q.S.T.*, 7, 7).

A NEW TYPE OF R.F. TRANSFORMER.—S. Kruse (*Q.S.T.*, 1, 5).

III.—MEASUREMENT AND CALIBRATION.

DIE EINFUNKENMETHODE FÜR MESSUNGEN MIT KONDENSATORSCHWINGUNGEN. — O. Meisser. (*Jahrb. d. drahtl. Tel.*, 22, 5).

DEKREMENTBESTIMMUNG, BESONDERS VON STARK GEDÄMPFTEN KREISEN MITTELS STOSSERREGUNG UND EINFUNKENMETHODE.—O. Meisser. (*Jahrb. d. drahtl. Tel.*, 22, 5).

PIEZOELECTRIC CRYSTAL RESONATORS AND CRYSTAL OSCILLATORS APPLIED TO THE PRECISION CALIBRATION OF WAVE-METERS.—George W. Pierce (*Proc. Amer. Acad. Arts and Sci.*, 59, 4).

IV.—THEORY AND CALCULATION.

SOME NOTES ON CALCULATING THE INDUCTANCE OF COILS.—E. J. Hobbs (*W. World*, 233).

CALCULATIONS OF CAPACITY.—E. J. Hobbs (*W. World*, 234).

WIRELESS TELEGRAPH THEORY.—Alfred A. Robb, Sc.D., F.R.S. (*Electn.*, 2386).

V.—GENERAL.

DESIGN OF LOOP ANTENNA.—Ralph B.tcher (*W. Age*, 11, 5).

K.D.K.A. EXPERIMENTAL WORK ON THE RELAYING OF AMERICAN BROADCASTING.—W. J. Brown, B.Sc. (*W. World*, 235).

LOW CAPACITY INDUCTANCE COILS.—H. F. Haynes (*W. World*, 235).

HOW TO DESIGN INDUCTANCE COILS.—Samuel C. Miller (*W. Age*, 11, 5).

A PROPOS DE LA CAPACITÉ DES CONDENSATEURS.—Michel Adam (*R. Elec.*, 5, 52).

LA PROPAGATION DES ONDES ET LES INSECTES.—F. Marre (*R. Elec.*, 5, 53).

UBER AUSBREITUNGSVORGÄNGE UND EMPFANGSSTÖRUNGEN IN DER FUNKENTELEGRAPHIE.—F. Kiebitz (*Jahrb. d. drahtl. Tel.*, 22, 5).

OSCILLOGRAPHE CATHODIQUE POUR L'ÉTUDE DES BASSES, MOYENNES ET HAUTES FRÉQUENCES.—A. Dufour (*L'Onde Electrique*, 11, 12, and 13).

DIE STEUERUNG VON HOCHFREQUENZSTRÖMEN DURCH EISENDROSSELN MIT ÜBERLAGERTER MAGNETISIERUNG.—L. Pungs. (*Elektrot. Zeitschr.*, 1923).

HIGH VOLTAGE PHENOMENA.—F. W. PEEK (*J. Frank. Inst.*, 197, 1).

UBER DIE GÜLTIGKEIT DES OHMSCHEN GESETZES FÜR ELEKTROLYTE BEI SEHR HÖHEN FELDSTÄRKEN —Max Wien (*Ann. d. Physik*, 1924, 3-4).

POST OFFICE RADIO STATION, DEVIZES.—J. H. Reyner, B.Sc. (*Exp. W.*, 1, 5).

DIRECTIVE RADIO TELEGRAPHY AND TELEPHONY.—R. L. Smith-Rose, Ph.D., M.Sc. (*Exp. W.*, 1, 5).

VALVE MANUFACTURE: SOME GERMAN METHODS. —Dr. A. Neuburger (*Exp. W.*, 1, 5).

ELECTRICAL IMPULSES.—Dr. N. W. McLachlan (*Exp. W.*, 1, 5).

THE MAKING OF PURE SHELLAC VARNISHES.—J. F. Corrigan, M.Sc. (*Exp. W.*, 1, 5).

AMATEUR WAVEMETERS.—S. Kruse (*Q.S.T.*, 7, 7).

LOADED AERIALS.—P. K. Turner (*W. Trader*, 1, 12).

Correspondence.

To the Editor of EXPERIMENTAL WIRELESS.

SIR,—I notice that in his "Month's DX" for the February issue of this journal Mr. Ryan states that, as far as he is aware, the Swiss station XY has not been heard in this country yet. It may be of interest to know that signals were exchanged between XY and my own station as far back as March 12, 1923. I was listening in on about 200 metres on this date early in the evening, just after sunset, when I heard a faint C.W. station with an A.C. ripple cq-ing its heart out and sending the call XY. I immediately called him on C.W. with about 0·5 amp. in my aerial, and was promptly answered by him. Owing to qrm and qss we lost each other after a bit and never got in touch again.

The owner of XY, M. R. Luthi, sent me a card confirming the exchange of signals, stating that he was using two 5-watt valves and putting 0·4 amp. into his aerial.

My own reception was done on two valves, one H.F. and a detector.

Four hundred miles is quite a good distance for two-way working with only about 10 watts at each end, and I do not expect to repeat the test for many moons.

It is interesting to note that the arc station at Lyons does for M. Luthi what Northolt and Leafield do for us, inasmuch as the harmonics of YN produce "brouillage" on 200 metres, which, in the case of the communication mentioned above, was the factor limiting M. Luthi's ability to receive my signals. Evidently arcs will be arcs all the world over, and I am sure we will extend our sympathies to XY and other experimental stations similarly situated.

E. H. ROBINSON (2VW).

To the Editor of EXPERIMENTAL WIRELESS.

DEAR SIR,—With reference to the letter by Mr. Voss in the last issue of EXPERIMENTAL WIRELESS, and to my previous letter, I should like to make a few remarks. I must plead guilty to overlooking the point noted by Mr. Voss, *i.e.*, that the formula takes into account the actual height of the aerial. However, another, and, if anything, more important, point has been overlooked. All these

formulæ which we have about aerials, etc., are worked out for an aerial excited at its base; that is, in this case the value for the resistance is given for the point at which the aerial is excited—at the base. Now the resistance of an aerial increases from the base to the free end, and in about 99 out of 100 cases in amateur stations the aerial is excited very considerably nearer its centre. In the case under discussion the aerial is excited at its centre, and is badly screened, the result being that the radiation resistance is apparently the same as if it were excited at the base, because the two conditions happen to cancel more or less: for objects in the immediate field of an antenna reduce its radiation resistance.

Unfortunately there was a rather serious misprint in my previous letter. The last sentence should have read: "and only serve as a very *rough* guide." It seems that we need something far better than the present formulæ before we attempt to apply them at all rigidly.

With regard to the thick wire question, I should like to bring out another point. Certain experimenters have tested coils wound with varying gauges of wire to the same pitch. They found an increase in efficiency as the size of wire was reduced up to a point, after which the results fell off again. Now a contingent point is the reduction in self-capacity due to the spacing of the turns. What is happening is that the eddy current losses and apparent resistance due to self-capacity are being reduced, but the true H.F. resistance of the wire is increasing as the size of wire is reduced. This naturally leads one to say that there is an optimum gauge of wire for a coil and optimum spacing for a definite frequency. A few calculations lead me to say that, in the case of a fairly large diameter single-layer coil, the optimum wire size and spacing are round about 20–22 S.W.G. and $\frac{1}{8}$ in. This has been confirmed by practice here, but a very great many more calculations must be made before the matter can be settled. Possibly someone who wants a job will tackle it!—Yours faithfully,

37, Bishop's Road, N.6. FREDERIC L. HOGG.
February 12, 1924.

To the Editor of EXPERIMENTAL WIRELESS.

DEAR SIR,—There are one or two points in connection with Mr. Voss's letter in the February issue of EXPERIMENTAL WIRELESS to which I should like to reply.

First, a minor point—he quotes the case where the local oscillations are smaller than the incoming signal, and refers to the extra selectivity obtained by a limiting action. If he will read my letter again, he will see I refer to that, and readily admit it.

Secondly, if Mr. Voss could give me an explanation of "grid condenser and leak" rectification without reference to the curvature of the grid-current—grid-volts curve I should indeed be grateful, as I cannot conceive of how a valve used in this way could possibly rectify on a linear grid characteristic.

Now with regard to the original problem, it seems to me that it is no use continuing to argue on the lines of purely physical explanation, as this does not take into account what is happening inside the valve, and is, in any case, somewhat unsatisfactory owing to its obvious lack of precision.

Let us consider the case where two E.M.F.'s are applied to the grid of the rectifying valve, "a. sni pt," due to the signal and "b. sin qt" due to the local oscillator. The resulting E.M.F. (v) is then given by:

$$v=a.\sin pt+b.\sin qt \qquad (1)$$

And this will be a sine wave of frequency $\frac{p+q}{2}$ and of amplitude varying between $(a+b)$ and $(a\sim b)$.

If $a>b$ the beat amplitude will then be $2b$, which is a case we need not consider.

If $a=b$ *or* if $a<b$, the beat amplitude will be $2a$.

Thus, with $a=b$ we have the *maximum value of beat amplitude*, which, as Mr. Voss says, is what we want, but it is absurd to say that "it does not matter what proportion the rectified current bears to the unrectified." But the maximum value of beat amplitude is *also obtained if* $b>a$, so we must proceed to see what effect this has when it is applied to the rectifying valve.

The equation for the characteristic curve of a valve (whether it be the grid-current—grid-volts or the anode-current—grid-volts curve) can be expressed in the form of a power series:

$$I=A+Bv+Cv^2+Dv^3+ \qquad (2)$$

where I = anode current, v = volts applied to the grid, and A, B, C, etc., are constants depending on the construction of the valve.

Now the lower part of a characteristic curve very roughly follows a square law, so we might as a first approximation write (2) as follows:

$$I=A+Bv+Cv^2 \qquad (3)$$

Substituting the value of "v" obtained from (1), we get:

$$I=A+B\,(a.\sin pt+b.\sin qt)+C\,(a^2\sin^2 pt+b^2.\sin^2 qt+2ab\sin pt.\sin qt).$$

This may be written:

$$I=A+B\,(a.\sin pt+b.\sin qt)+a^2C\,(1-\cos 2pt)+b^2C\,(1-\cos 2qt)+2abC\left[\frac{\cos(p+q)t}{2}+\frac{\cos(p-q)t}{2}\right]$$

In this expression the only term producing *audible* note in the phones is part of the last one, the actual value being:

$$abC.\cos(p-q)t \qquad (4)$$

Now by inspection of (4) it would appear that the greater the value of b, the greater would be the resultant note in the phones. This is not, however, strictly true, since we have assumed that the valve characteristic is satisfied by equation (3).

We cannot really get very near the true state of affairs unless we include another term from the power series, the equation then being:

$$I=A+Bv+Cv^2+Dv^3 \qquad (5)$$

The effect of the addition of this term is that there is an *optimum* value for b which is *greater than* "a."

The whole matter is dealt with at length, including experimental results, in a paper by Dr. E. V. Appleton, entitled "Optimum Heterodyne Reception," which should shortly appear in the *Proceedings* of the American Institute of Radio Engineers.

I cannot see how the case for equal amplitude of local oscillations and signal oscillations holds good under *any* conditions. (I am not considering the case of selectivity).

I have taken the simplest (though not strictly true) case, and it certainly does not hold there, and it does not hold for a four-term power series, as

shown in Dr. Appleton's paper. So where does Mr. Voss get his theory from ?

Apart from the pure theory, E. H. Armstrong has shown with curves obtained from *experiments* that the telephone current gets greater as the amplitude of local oscillations is raised *above* that of the incoming signal (*Proc.*, I.R.E., Vol. 5, p. 145, 1917).

Speaking from memory, I think he shows that the value of the ratio of strength of telephone current when optimum heterodyne point is used, to that obtained when the amplitude of the local oscillation is *equal* to that of the signal, is of the order 55 to 1.

I do not pick any definite holes in either Mr. Voss's or Mr. Ryan's theories, simply because they are stated in a form in which one cannot say that this or that is definitely wrong (or, for that matter, right !), therefore, I quote the theory I am working on.

In his letter, Mr. Voss states : "If the local oscillations are . . . stronger . . . than the incoming signals, the beat amplitude suffers . . . " *Why ?*

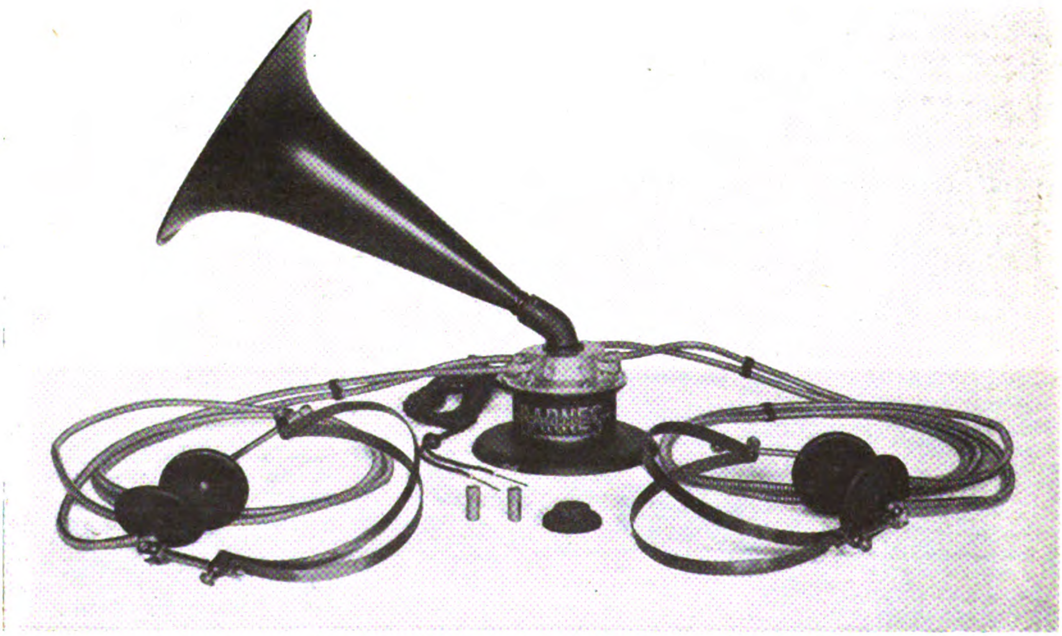
It would appear from the foregoing that this is anything but true. If Mr. Voss's statement is true, how does he explain (1) the results of Armstrong's experiments, and (2) where does he find the error in the reasoning I have used above ?—Yours faithfully,

DESMOND DE BURGH,
F/L., R.A.F.

Business Brevities.

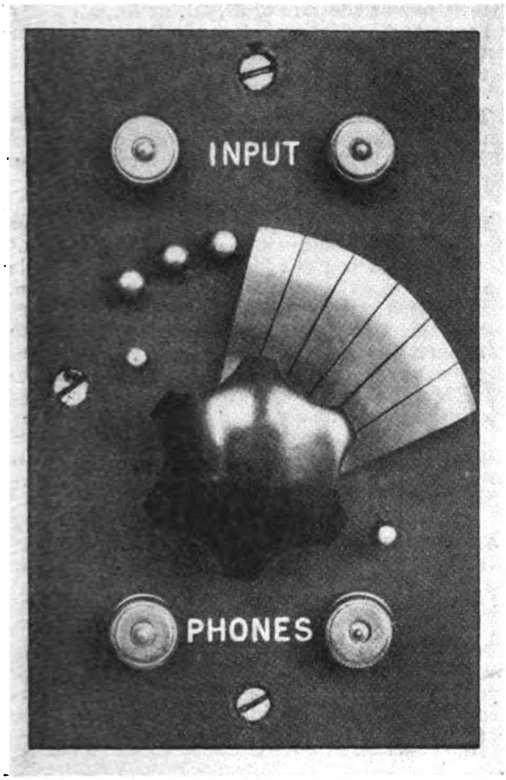
THE BARNES' MULTIPHONE.

The Barnes' Multiphone seems to be the really first application of a principle which was suggested, and, in fact, tried out, some years ago. Briefly described, it consists in causing a common diaphragm to excite an air chamber fitted with a number of outlets which communicate with a number of earpieces or other devices. The Multiphone is shown in the accompanying illustration, and the method of construction should be readily apparent. The movement comprises a substantial magnetic circuit with a fairly thick adjustable diaphragm. The air chamber somewhat resembles a capstan head, and is provided with a number of tapering slots arranged radially into which can be plugged the headphone "leads." These, of course, are merely flexible tubes, terminating in "earpieces" consisting essentially of pressed metal discs fixed to a light head-band. The top of the air chamber contains a larger tapering hole, into which a loud speaker horn can be fixed. When the horn is not required the hole is closed with an ebonite "stopper," and similarly the headphone leads may be replaced by small metal plugs. On test



The Barnes Multiphone provides for a loud speaker horn and four pairs of headphones.

the headphones gave very good quality reproduction and fairly good strength considering that four pairs were in operation simultaneously. The tone is rather on the deep side, but is certainly not too deep. We were not quite so pleased with the volume from the loud speaker, but on normal load the quality was quite good. After being accus-



Showing the construction of the switch on the Fuller Tone Controller.

tomed to ordinary telephone leads, the comparatively heavy flexible tubing seemed to make its presence well known ; perhaps it might be possible to substitute it by rubber tubing. The Barnes' Multiphones should appeal to those interested in headphone reception of broadcasting, since four pairs of telephones and a loud speaker are available at practically the same cost as that of a small loud speaker.

* * *

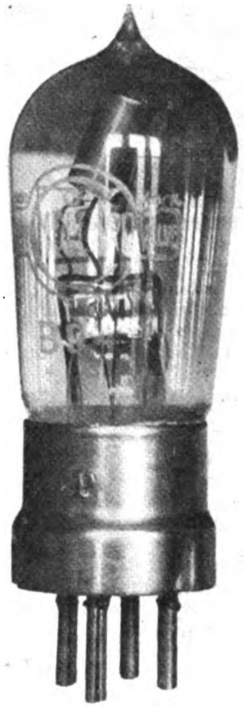
The Fuller Tone Controller.

We have received for test from Messrs. Fullers United Electric Works, Ltd., one of their standard tone controllers, which is shown in the accompanying illustration. As its name implies, it is intended to control the tone of music or speech in the telephones or loud speaker. It will be seen that there are two input and two output terminals, which are connected respectively to the output of the set and the telephones or loud speaker. The device is fitted with a special six-leaf radial switch, which connects in parallel a number of studs communicating with a series of condensers connected in parallel with the input and output terminals. In operation it is found to be very effective in altering the tone of the received signals, and in particular one can usually find a best setting for speech and a best setting for music. To those of refined musical tastes it should make a special appeal.

* * *

Another Ora Valve.

The O.R.A. "A" and O.R.A. "B" valves are too well known to need any introduction to our readers. Another has now been added to the group in the form of the D.F. O.R.A., which is somewhat similar to the original types, but is made with a thoriated high-resistance filament similar to that used in the UV199. The shape and position of the electrodes can be gathered from the accompanying photograph. The filament current is 60 milli-



The new D.F. Mullard ORA.

amps. at 2 to 3 volts, with a fairly heavy emission, as much as about 12 milliamps. being obtainable. With 100 volts on the anode a grid-bias of about 5 volts is required when used as an amplifier. The valve should be especially useful for compact portable sets where battery power is limited. We would remind our readers that a valve with so thin a filament requires very careful handling.

Experimental Notes and News.

The next Wireless Exhibition under the auspices of the National Association of Radio Manufacturers will be held at the Royal Albert Hall, London, during the last week in September next and the first week of October. It is intended to demonstrate present-day wireless achievement under the best possible circumstances.

* * *

The time signals broadcast from London are now sent direct from Greenwich Observatory, instead of from Paris.

* * *

The morning broadcast concert from 2LO is to be resumed at an early date. This is a concession to night-workers who are unable to listen to the usual programmes.

* * *

Sir Henry Thornton, the President of the Canadian National Railways, is arranging to provide wireless receiving sets for 100,000 workers on that company's line. Broadcasting stations will be established at various points of the 22,000 miles of railway, and sets will be supplied to the workers at cost price.

* * *

It has been stated that over 12,000 miles of aerial wire have been erected in Britain during the past twelve months. Over £100,000 has been paid by the British Broadcasting Company in fees, copyright royalties, and salaries for the wireless concerts.

* * *

Australia's first broadcasting station has been established at Willoughby, eight miles north of Sydney. A cage aerial 575 feet long, is used, supported between two towers 200 feet high. The wave-length is 1,100 metres, and the call is 2FC.

* * *

Complaints of oscillations in the London area are recorded at B.B.C. headquarters by inserting pins in a map. The pins are removed once a month when the complaints have been investigated and cleared up. Forest Gate, Stratford, Acton, and Ealing are the districts where most trouble has recently been experienced.

* * *

The Government of India are inviting applications from private enterprise for licences to establish and operate the necessary radio service to provide the Indian link in the Imperial Wireless Scheme. The service required entails the installation of a station capable of conducting high-speed duplex radio communications in two directions simultaneously, together with simultaneous reception from at least three other directions, at a rate of charge which shall not exceed the cable rates from time to time prevailing. Direct communication with the United Kingdom or South Africa on the one hand, and Australia or Canada on the other, must be guaranteed.

* * *

It is stated that owing to the depression in the shipping industry, more than 2,000 competent marine wireless operators are unemployed. On the other hand, there appears to be a shortage of operators in the Royal Air Force. In the latter service, all wireless operators will be given the rank of Leading Aircraftsman or Aircraftsman (First Class) as soon as the attestation test has been passed, according to the skill shown. This carries with it pay at the rate of 5s. 2d. or 4s. 6d. a day. All operators are fed and clothed. By attaining the rank of first-class sergeant-major it is possible to obtain pay at the rate of 15s. a day.

* * *

The Liverpool Relay Station is to be constructed immediately after the completion of the Edinburgh Station. B.B.C. engineers have already visited Liverpool to examine possible sites.

* * *

The British Broadcasting Company are considering the establishment of a new high-powered broadcasting station just outside the London area. The proposal is to put up a 25-kilowatt plant, working on a wave-length of 1,600 metres. It is thought that the new station, if definitely proceeded with, will facilitate crystal reception up to 100 miles, single-valve reception up to 200 miles, and two-valve reception anywhere in the United Kingdom. Permission has already been given by the Postmaster-General to erect such a station for experimental purposes. A permanent license would be subject to the new transmission not interfering with Government services.

* * *

Dundee is anxious to have a relay broadcasting station. A sub-committee of the Town Council has been appointed to interview the G.P.O. officials and others in connection with the scheme.

* * *

A demonstration of a new device for preserving the secrecy of wireless messages has been recently given in Birmingham. The device provides for the reception on one aerial and one receiver messages of two, three, or any number of different wave-lengths. By transmitting messages of which the alternate words were on different wave-lengths, in accordance with an agreed code, secrecy would be preserved.

* * *

The Housing Committee of the London County Council have decided to dispense with the deposit which was required from tenants desiring to instal wireless apparatus. A deposit of £1 is, however, still required from tenants of block dwellings.

* * *

On a recent trip of the *Aquitania* the wireless aerials were arranged to work one on 600 metres and the other on 1,200 metres. By working a double shift, messages were handled with much greater ease than usual, and during the voyage 100,000 words were transmitted as against 60,000 on a normal voyage.

* * *

Complaints are being made that the Radio Corporation of America have established a monopoly in wireless apparatus in restraint of trade. The Corporation comprises a number of the leading wireless manufacturing companies in the United States, and the Federal Trade Commission has entered a charge against them.

Experimental Wireless

A JOURNAL OF RADIO RESEARCH AND PROGRESS

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Experimental Topics.

B.B.C. Activities.

No one could justly insinuate that the British Broadcasting Company is showing lack of enterprise. In fact their present activities are such as to arouse more than a passing interest amongst the more serious wireless experimenters. It is now common knowledge that the B.B.C. are seriously considering the erection of a high power central broadcasting station, and the announcement has given rise to considerable criticism. Capt. P. P. Eckersley, their chief engineer, too well known to our readers to need introduction, has written to us at some ength, and his communication is both an endeavour to justify the adoption of the suggested scheme and to reply to the chief cirticisms which have been levelled against it. The B.B.C. admit that simultaneous broadcasting is not all that can be desired, and that in the future provincial stations could relay a central station by a "wireless link" which would be immune from line troubles. Then there is the case of the man with a crystal set situated midway between two stations. At present his position is practically hopeless, and the only suitable solution lies in the use of greater power. Another point in favour of the "High Power'd Station" is that local jamming would be proportionately negligible. "But what is to become of the listener with a receiver embodying only short-wave tuned circuits?" say the critics. "Buy or build loading coils" is the reply. This is certainly wise counsel, but we ourselves imagine that it will be a rather difficult problem for those whose sets employ one or more stages of H.F. amplification not provided with interchangeable coils. But then, of course, there is no need to listen to the new station, for the service is to be additional to that already existing, and so far as the broadcast listener (or "B.C.L." as he is known in the States) is concerned, the proposition seems highly attractive. When we examine the technicalities of the scheme we find it is proposed to employ about 25 kilowatts of well modulated C.W. on 1,600 metres—something resembling a fairly well-tuned spark station. We do not wish to make any suggestions concerning the possible jamming that may arise, as we have before us no definite data, but we wonder what methods of telegraphic reception will be necessary round about 1,500 metres for stations situated in the immediate vicinity. Turning, now, to recent events, many readers have mentioned the relayed 100-metre American stations and have asked us if we know why the tests have been made, as they have received chiefly distorted speech and atmospherics. Frankly we cannot offer any suggestion, and regard the transmissions more as a scientific experiment than an entertainment. It is absolutely impossible to predict transatlantic reception conditions, and so far the B.B.C. seem to have been unlucky in the choice of dates. We venture to submit that transatlantic 100-metre transmission and recep-

tion still needs considerable investigation. So far as relaying is concerned night distortion eems to be the chief drawback, and it would no doubt be a wise policy to conduct further research in reception before continuing the relaying of American programmes. However, the B.B.C. are to be congratulated on their enterprising experiments, and we trust that future tests may be more successful.

Amateur Transmission and Broadcasting.

Under the heading of "Points from Letters" will be found some correspondence on the subject of broadcast jamming by amateur transmission. As will be seen, the alleged amateur jamming was really non-existent, the interference being due to a high-power station. However, the letters in question serve to indicate the attitude of the broadcast listener towards the experimenter, and there is no doubt that many "B.C.L.'s" seem to feel that their 10s. or 15s. licence entitles them to all the æther. The experimenter and "B.C.L." have an equal "right to the æther," and no genuine experimenter wishes to cause interference. There is no reason why he should not transmit occasionally during broadcast hours, and if jamming takes p ace it is due to the inefficiency of the broadcast receivers. In the latter case there should be some pleasant mutual arrangement between the parties concerned. Perhaps "B.C.L.'s" would find greater favour in the sight of the experimenter if some of them were a little less demonstrative and a little more reasonable. It is a great satisfaction to know that the Post Office have at heart the freedom of the experimenter and will do all they can to help him.

First Principles.

Some little while ago we were present at a meeting of one of the well-known wireless societies which holds regular meetings in London and has the support of several well-known radio engineers. A most interesting paper was read, and the ensuing discussion clearly demonstrated that the speaker's remarks had been closely followed by his listeners. Both the paper and the discussion were unquestionably illuminating, but, unfortunately, several statements and suggestions which were offered showed a considerable ignorance of some of the elementary fundamental principles of electricity. Perhaps, however, this may not have been due to entire ignorance, but rather to the speaker's inability to apply fundamental principles to any particular problem. We cannot impress too fully upon our readers the extreme value of some knowledge of elementary physics and electricity. Without such all experimental work is mere blundering in the dark, and results are achieved rather by accident than design. The ignorant experimenter is surely more an automaton than a scientific investigator. Admittedly it may seem more pleasing to experiment with some wonderful multiple circuit or freak reflex arrangement, for example, but the joys are merely transient. If the time were to be devoted to a little straightforward experiment conducted in a true scientific manner the radio enthusiast would soon find that he was in a position to master his apparatus instead of being subject to its sway. Similar reasoning holds good in the case of literature, and the experimenter who devotes a little time to simple text books rapidly rises above those whose interest lies only in light reading. The greater the knowledge and skill of the amateur the stronger will be his position. British experimenters must see that they lead the way in amateur radio work.

Amateur Construction.

A large proportion of amateur-assembled apparatus sent in for calibration has revealed many mechanical defects. Apparently, the radio enthusiast seems satisfied so long as his apparatus functions in the desired manner. There is no use denying the fact that almost any collection of gear, if correctly connected, will function, but the amateur should remember that in many cases electrical and mechanical efficiency are correlated, and it frequently happens that the former cannot be a maximum without paying due regard to the latter. We refer particularly to such instruments as variable condensers and other moving parts, such as switch arms. Rigidity of mounting of all components of a high frequency circuit is also of the utmost importance. In order to assist our readers in this direction we shall give from time to time some short notes on these and similar subjects, and we feel that information from the pen of a mechanical engineer should be of great assistance.

The Electromagnetic Screening of Radio Apparatus.

By R. L. SMITH-ROSE, Ph.D., M.Sc., D.I.C., A.M.I.E.E.

It might appear at first sight that the problem of screening any particular arrangement of apparatus is comparatively simple. This, however, is not the case, and below will be found the results of a considerable amount of experimental work on screening at high radio frequencies.

I.—General.

ALL those who have carried out experiments in connection with radio apparatus will have appreciated the fact that the shielding or protection of a body or space from a high-frequency electromagnetic field is very much more difficult than is the case when using steady electric or magnetic fields. Electrostatic screening may be effectively carried out by completely surrounding the body with a metal covering, (a Faraday cage), the thickness of which is immaterial. Where it is desirable to be able to inspect the interior the screen need not be continuous but may be constructed of metal gauze or perforated sheet, without sacrificing appreciably any of the screening properties for steady electric fields. Magnetic shielding of a body may be carried out by surrounding it with a heavy iron case which, however, only partially screens by deflecting the magnetic field through the space of greater permeability.*

When the magnetic field is fluctuating or alternating the shielding effect of the iron is much more complete, and in this case also the shielding may be produced by other metals than iron due to opposing effects of the eddy currents set up in the metal by the primary fields. Simple experiments with oscillation generators give the impression that when the frequency of the alternating magnetic field is very high the difficulty of screening is greatly increased. This is, however, a false conception and arises from the fact that the induced e.m.f. in any circuit placed in an alternating magnetic field is directly proportional to the frequency, and thus weak fields give a comparatively large induced e.m.f. at the frequencies employed in radio work. It is this fact, together with the very high magnifications produced by multi-stage valve amplifiers, that leads to some rather surprising results when attempts are made to shield instruments from radio-frequency alternating magnetic fields. In actual fact the difficulty of reducing a field to a given fraction of its value decreases as the frequency is increased.

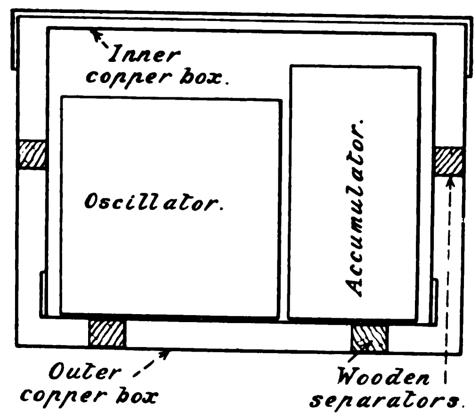

Fig. 1.—Triode oscillator screened with two complete copper boxes.

II.—Some Experiments on the Screening of an Oscillator.

(*a*) PRELIMINARY EXPERIMENTS.

Although most experimenters will need to carry out screening at the receiving end of their apparatus it is convenient to experiment on a source of oscillations. The fields so obtained will, in general, be much larger than those experienced in reception and the effects of the various screens will thus become much easier to detect. In the experiments about to be described no convenient means of measuring the induced e.m.f. from the local oscillator was available, and this made the carrying out of the experiments somewhat difficult.

To ascertain the general nature of the problem of screening preliminary experiments were carried out with a simple form of valve oscillator of the usual type. The 6-volt accumulator for the filament also served as the H.T. supply, so that the oscillations generated may be described as relatively weak. When receiving strong C.W. signals on a frame coil about 4 feet square and using a 7-valve amplifier, however, this oscillator was sufficient to give a beat note which was audible several yards away from the telephones even when the oscillator was placed at a distance of 100 feet from the coil receiver. This indicates how very small is the local oscillating current required to heterodyne incoming signals. In the majority of the experiments the continuous wave signals received by the frame were produced by a second oscillator which was coupled to the receiving coil.

Attempts were now made to screen the first oscillator to obtain a reduction of the stray field from it which links the frame coil receiver. The oscillator with its battery and connecting leads were therefore first

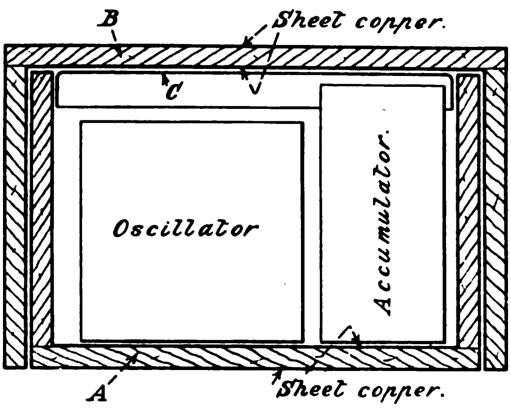

Fig. 2.—Simple screened oscillator.

A=Double copper-lined wooden box.
B=Double copper-lined wooden lid.
C=Inner copper lid.

placed inside a thin copper box provided with a loosely fitting lid. This considerably reduced the intensity of the corresponding oscillations induced in the receiving coil, and they were only effective in producing a beat note when the oscillator was brought within 20 feet of the coil. With a box of galvanised iron in place of copper a similar reduction of the induced oscillations was obtained of about the same order. In both these cases it was observed that the placing of the lid on the box had a considerable effect on the reduction ; but the position of the otherwise open end of the box relative to the receiving frame appeared to be immaterial. A lid of fine brass wire gauze was not so effective as a solid sheet of metal, whether copper or iron.

With the oscillator and battery inside the copper box this in turn was supported on paraffin blocks inside the iron box with the respective lids in position. This arrangement only resulted in an audible beat note when placed within 12 feet of the coil. By using a small coil in the amplifier circuit as a search coil it was found that a considerable increase in the strength of the note was obtained with this coil placed near the aperture between box and lid, indicating that some at least of the energy escaped in this direction. Making metallic connection between the copper and iron box had no effect on the strength of the received signal. Further experiments showed that the copper box provided with a well-fitting lid giving about 3 ins. overlap was much more effective in screening than with the lid formerly employed only ½ in. deep.

(*b*) BOXES WITH MULTIPLE COPPER LININGS.

As the combined copper and iron boxes seemed to give hopeful results further experiments were carried out with boxes with two and three linings. One such arrangement consisted of two copper boxes complete with close-fitting lids and separated from each other by 1 in. wooden strips. This arrangement was found to screen most efficiently when the inner box was inverted, as shown in Fig. 1. Again no difference was experienced on making contact between the two boxes.

For the next experiment a rough screening box was constructed of the form shown in the diagram in Fig. 2. Both the lower and upper halves A and B of the box were lined inside and out with thin copper sheet on a wooden frame, and the upper lid B was arranged to completely envelop the lower-half A. With this box it was found that putting on the lid made a considerable reduction in the escaping energy from the oscillator as indicated by the diminution in intensity of the note heard in the telephones. The box appeared in fact to be about as good as the combined copper

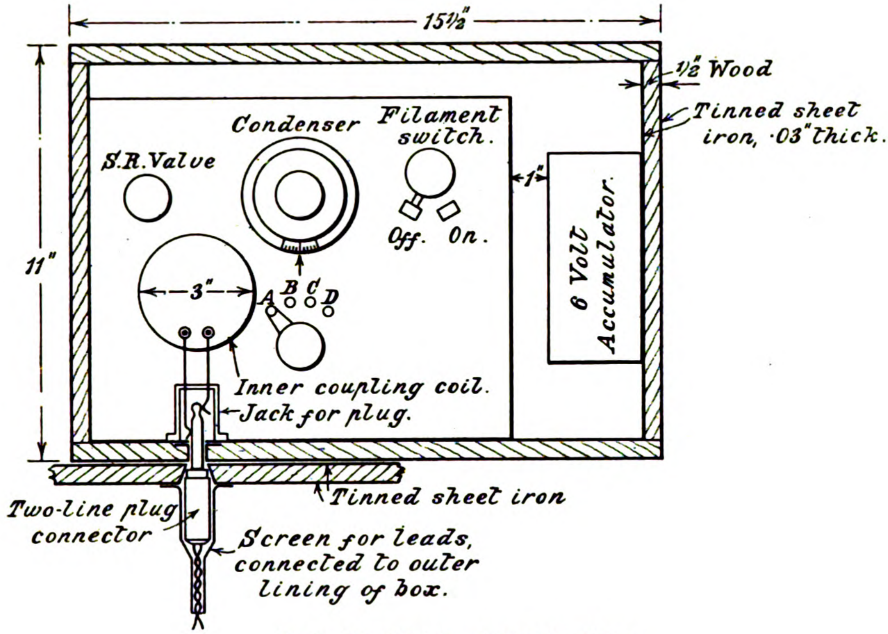

Fig. 3.—Plan of interior of screened oscillator.

and iron boxes previously tried, but was much more convenient from the point of view that the double-lined lid could be removed at one operation. The diminution effect was continuous as the lid was placed over the box, the telephone intensity being a minimum when the box was completely enveloped. It was subsequently found that the fitting of an auxiliary inner lid, as shown at C in Fig. 2, effected a still greater reduction in the emitted energy.

(*c*) EFFECT OF LEADS PROJECTING FROM THE BOX.

With a type of double-screened box as used above (Fig. 1) the external field could be rendered inappreciable when it was at a distance greater than 12 ft. from the frame coil receiver. In this condition a small coupling coil of a few turns was introduced into the inner box and a flexible conductor brought outside the whole enclosure. As long as this conductor remained entirely within the outer iron box the beat note was undetectable at 15 feet distance, but immediately a few inches of it were exposed outside the iron box good beat note signals were obtained, giving evidence of energy thrown off from these leads. Replacing the flexible wires by a lead-sheathed twin conductor overcame this trouble, which, however, recurred on connecting a small coil to the end of the screened leads with a view to coupling to the amplifier. In later experiments the construction of the coil in two halves of D shape wound in opposite directions was found to be a suitable manner of overcoming the difficulty.

III.—Experiments with Metallically Sealed Boxes.

(*a*) SEALED COPPER BOX.

Using one of the original boxes of sheet copper about 30 mils. thick, all joints at sides and bottom were sweated together with about ¼ in. overlap. With a well-fitting lid made of the same copper sheet and giving about ½ in. overlap, the external field from the oscillator within the box was easily detectable when the box was within 20 feet of the receiving set. Without altering any of the adjustments the box and lid were solidly soldered up using a good thickness of solder to cover all holes and cracks. In this condition the effect of the oscillator could still be detected when within 10 feet of the frame coil. When the box was placed inside the frame the beat note in the telephones could be heard 100 feet away. Also by

tilting the box inside the frame a position giving practically dead silence could be obtained in the same way as with the oscillator unscreened.

The effect of hermetically sealing up this copper box was therefore to reduce some of the emitted energy which presumably came from the cracks round the lid, while still leaving a very appreciable amount apparently passing through the metal; the external field retaining the characteristics of that from the unscreened oscillator.

up as before, after which no beat note was audible in the telephones, even when the box was placed inside the frame receiving coil. The fact that the oscillator was still in operation undisturbed was proved by making a slit in the box, when a beat note was easily heard in the telephones. A subsequent repetition of this experiment showed that enough energy escaped through a slit ½ in. long to be easily detected. Further experiments indicated the absolute necessity of stopping all holes and cracks and of getting

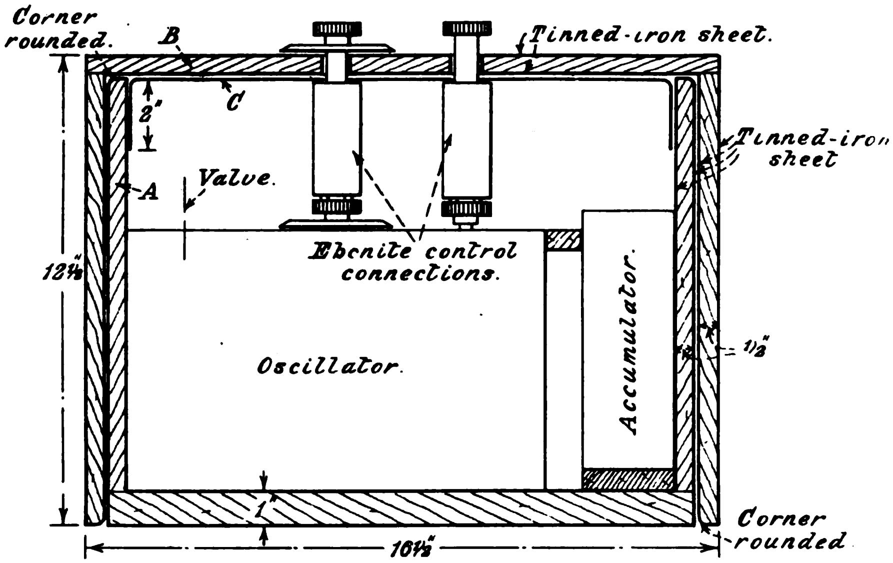

Fig. 4.—Sectional elevation, showing tinned-iron sheet linings, and control handles.

good metallic contact across all the joints, as a "dry soldered" joint may easily be the cause of an external magnetic field.

(*b*) Sealed Iron Box.

A similar experiment was next carried out with a box of the same dimensions constructed of sheet iron 28 mils. in thickness. When the oscillator was placed inside the box, with a well-fitting lid giving ⅜ in. overlap, the resulting beat note signals were about the same as for the copper box. Placing another iron covering over the lid caused an appreciable diminution in the signals, but no further reduction was obtained by covering the remainder of the sides of the box. This seemed to indicate that the major portion of the energy from the inner box was coming from under the lid.

Employing the same oscillation frequency (which corresponded to a wave-length of 2,400 metres), the box and lid were soldered

These experiments indicate, therefore, that it is only possible to screen a valve oscillator completely, as far as the sensitivity of the above apparatus goes, by placing it inside a sealed box of tinned sheet iron of sufficient thickness to prevent the direct penetration of the high-frequency magnetic field through it. In the latter respect iron would appear to be far superior to copper, which is a result in complete accordance with the theory of the penetration of alternating currents into conductors. This theory indicates that iron should be equivalent to about four to six times its thickness in copper. It is probable, therefore, that if experiment (*a*) above were

repeated, using a box of $\frac{1}{8}$ in. copper sheet, complete screening would also have been obtained. From theory also it may be shown that the thickness of metal required to reduce a field to any definite fraction of its original value varies inversely as the square root of the frequency. Thus, to give the same effect at a frequency of 100 as is obtained at 1,000,000 cycles per second by $\frac{1}{8}$ in. of copper requires a thickness of about 12 inches of the same metal or about 2 inches thickness of iron !

depth of $\frac{1}{2}$ in. to close all cracks was found to entirely stop all detectable field, even when the box was placed inside the frame. On raising the box at one side the smallest crack was immediately detected by the note in the telephones. Using the copper box in the above manner, however, a beat note was still obtained when the mouth of the box was below nearly 1 in. of mercury.

This comparison experiment is very striking. With the copper box placed over, the the beat note steadily diminishes in strength, and a just detectable drop in intensity is noticed when contact is made with the mercury and the last crack closed up. With the iron box, however, the drop in intensity to entire inaudibility when contact is made with the mercury is very sudden and is a most marked effect. These experiments were repeated for oscillations corresponding to various wave-lengths over the range of 2,000 to 9,000 metres, and the residual effect with the copper box was found to be slightly increased at the higher wave-lengths, *i.e.*, at the lower frequencies.

These results thus fully confirm those previously obtained and indicate that the most complete method of screening valve

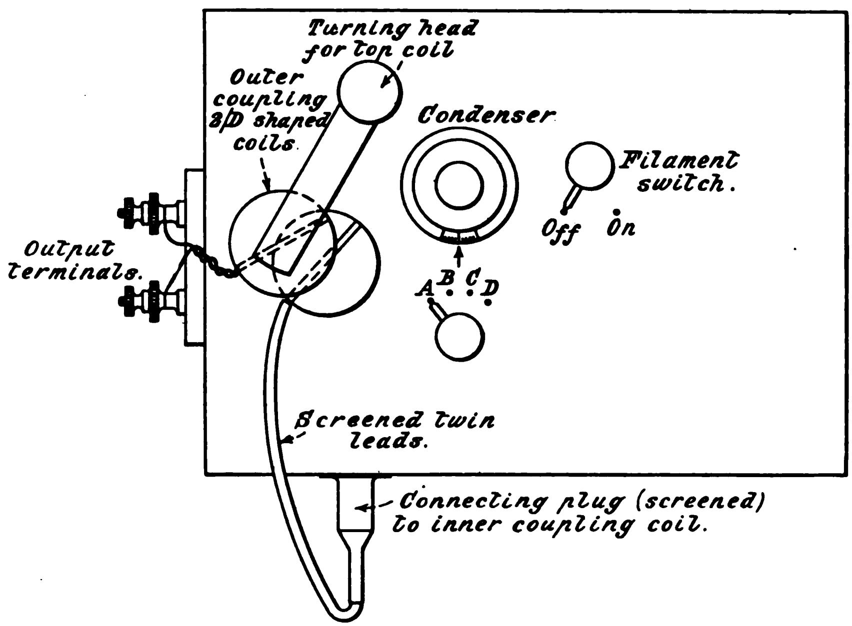

Fig. 5.—Plan of exterior of screened oscillator.

(*c*) Mercury Sealed-Boxes.

The process of soldering and reopening metal boxes containing a valve oscillator is very laborious and considerably limits experiments on these lines. It was thought that a mercury seal, if of sufficient thickness, would be as effective as solder in stopping up holes and cracks.

A suitable tray about $2\frac{1}{2}$ ins. deep was therefore made on which either the copper or the iron box could be placed giving an all-round clearance of about $\frac{1}{2}$ in. Placing the oscillator and battery in this tray with the iron box over it, the external field was easily detected when within 20 feet of the frame. Filling the tray with mercury to a

oscillator is to enclose it in an iron box with welded joints, the removable lid being provided with a mercury seal. All external controls must be reduced to a minimum or even eliminated, owing to the apertures through which it is necessary to bring them. Such an extreme case would be very difficult to work with in practice, and some slight departure is necessary for the design and construction of a practical apparatus.

IV.—Design of a Screened Oscillator.

In the present section a detailed description is given of an *almost completely* screened oscillator designed by the author, which has been found very convenient and satisfactory for use with wireless direction finders and

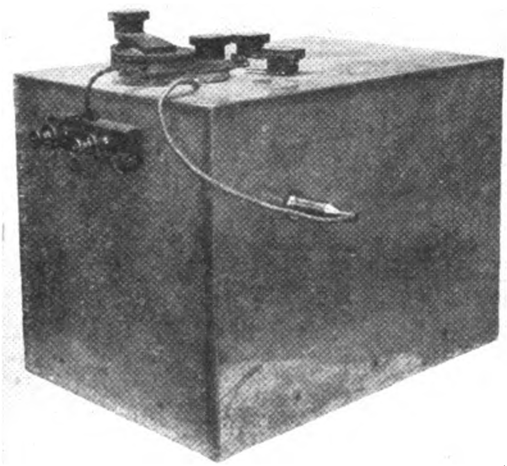

Fig. 6.—General view of oscillator showing controls.

with signal intensity measuring instruments The experiments had already shown that the next best arrangement to a sealed box was the provision of a tightly fitting lid with deep overlap, making good contact with the box over a large surface. In the present design the lid and box are of equal depth so that the former envelops the latter. The details of the design can be seen from the drawings in Figs. 3, 4 and 5. Both the box A and lid B are constructed of ½-in. five-ply wood, lined inside and outside with stout tin-plate. A lid C of depth 2 ins. is provided to complete the inner sheet metal lining, and the outer lid B is a tight driving fit over the box A to ensure good metallic contact between the respective surfaces.

Ebonite connecting pieces are used between the control handles on the top of the lid and the variable condenser, and the switches for filament current and inductance tappings within the box. Where they pass through the small apertures in the lid the controls are provided with metal bushes which make spring contact with the outer lining of the box. A separate coil is used within the box to couple to the oscillator inductances, and leads from this coil are brought out through the side of the box by a telephone jack and plug connection. The jack is mounted inside the box and the plug is pushed through holes in lid and box which are only in alignment when the lid is in its final position over the box. The plug is screened by a metal shield in contact with the outer lining of the box and the connections are taken through a metal sheathed twin flexible conductor to a double D-shaped coil forming half the outer coupling. Leads from the other pair of D-shaped coils are taken to the output terminals mounted on ebonite at the side of the box. A general view of the oscillator, showing the controls, is given in the photograph, Fig. 6, while Fig. 7 shows a plan of the interior of the box with the two lids.

The following points may be emphasised in regard to this screened oscillator.

(*a*). The entire control of the oscillator is obtained from the outside, and it need never be opened except for inspection, replacement of valve, or recharging of accumulator. A dull-emitter valve is used, and the filament supply is taken from a 6-volt accumulator, which forms the complete anode battery and which will run the set for about 120 hours continuously or intermittently.

(*b*). The opening up of the oscillator, when necessary, is a moderately simple operation. It entails the removal of the connection plug, control handles and the two screening lids.

(*c*). Close metallic contact is obtained at all points in the paths by which the high-frequency energy may escape from the box, other than by direct penetration through the sides.

(*d*). No part of the primary oscillator circuit is outside the inner metal lining.

Leads from the secondary circuit, which is untuned, are brought out by a screened conductor to an astatic coupling coil arrangement. The other half of this astatic coupling forms the tertiary output circuit to the measuring instrument. This coupling forms a convenient means of varying the strength of the output oscillation from a maximum down to nearly zero.

With this oscillator in operation a beat note was just detectable when it was placed about 5 feet from the frame coil receiver connected to its 7-valve amplifier, and the note was not very intense when the oscillator was placed inside the frame. Measurements are, of course, impracticable, but it is probable that the field has been reduced to about one millionth of its original strength.

V.—The Screening of Receivers.

For the screening of parts of radio receiving apparatus from stray electro-magnetic fields or for undesired incoming waves similar precautions must be taken on the general principles evolved from the above experiments. The chief point is to provide complete current paths in the screen of low resistance and in directions perpendicular to the undesired magnetic fields. Where the fields pass through the metal itself advantage can be taken of the permeability of iron to reduce the extent of the penetration. For general purposes, such as the screening of amplifiers, coil couplings, etc., a box of tinplate provided with a well-fitting lid and good overlap is very serviceable. To make the box non-directional in its action good conductivity must be ensured in all directions and the apertures necessary for control handles must be reduced to the minimum area. When the screening is not required to be as complete as in the above example wire netting or gauze of small mesh may be used, provided all slits are well-connected up. Such screens have been shown to reduce the field of an incoming wave to about 5 per cent. of its value outside the screen, and the use of solid metal sheet is only necessary in the not infrequent cases in which the reduction is required to be much less than one per cent.

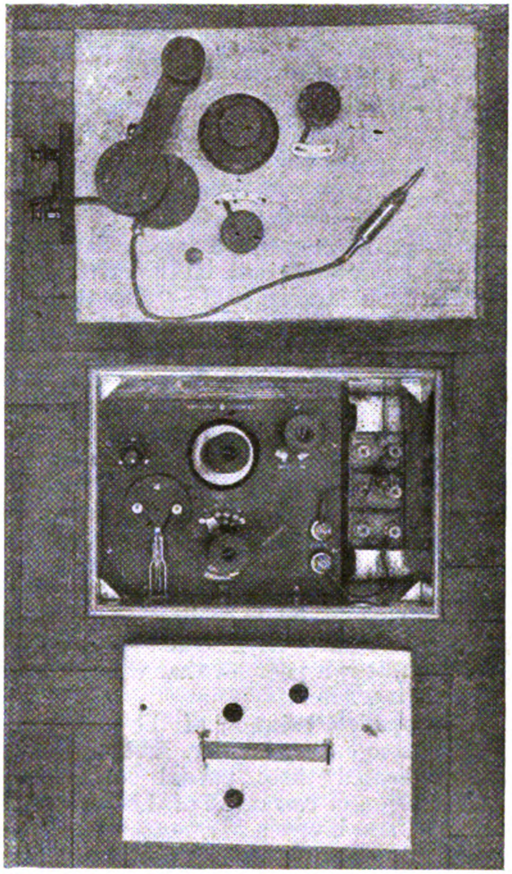

Fig. 7.—Plan view of interior of the box with the two lids.

Selectivity.

By L. J. VOSS.

Below will be found a brief review of the problems of selectivity and various methods of interference prevention are discussed.

IN 1899, when there were less than half a dozen radio stations on the earth, Dr. J. Erskine Murray said: "The difficulty in wireless is not to *receive* a signal, but to keep one *out*." How much more true is that to-day; yet how many design and build sets with this in mind? Few, deplorably few. An almost analogous case occurs in the practice of photography; the correct procedure is to expose for the shadows, leaving the latitude of the plate or film to deal with the high lights. Beginners—and some others who will never get far—fire away with a fine disregard for the principle. So in wireless, our ***main*** efforts should be directed to keeping interference out. With some success in this direction, it is a poor set that will not bring in what is wanted.

No complete solution of the problem of interference exists, but Dr. Erskine Murray has indicated three partial solutions: a combination of two or all of these is usually possible, and brings a fair measure of success within our reach. Directional transmission and reception, organisation, and selectivity are the three partial solutions referred to. Of these, it is proposed to deal with the last, as being more within the scope of amateur work than the others.

Transmission must be dismissed—or, perhaps, postponed—in a few words. All responsible for the operation of transmitters *should* keep within the allotted wave-band, avoid harmonics, etc., and should use no more power than necessary at any time. Dead sharp tuning is impossible, for to signal one must modulate in some way, and this means that a band of wave-lengths of greater or less width is occupied; decrement also plays a part. Telephony is the worst form of modulation from the point of view of interference production, both by spreading out over a wide band, and by heavy and variable decrement; next comes chopped C.W., then spark and tonic train (sine modulation), about on a level, followed by high speed C.W. Hand-keyed C.W. does not give much trouble in this way. Incidentally, it may be noted that the method of signalling by de-tuning adopted at most arc stations may be less troublesome than "on and off" methods. It is unfortunate that many transmitters at present in use are incapable of being adjusted to give pure narrow band transmission; but such apparatus tends to give place to better systems as time passes.

The ether hog, however, will probably survive for some years yet, and will trouble other people by carelessness in adjustment and by butting in out of turn, and with ten times the necessary power. As this type will *not* QRT (even when Land's End is insistent in the matter), we must provide every possible resource in the receiver for cutting out any anticipated form of interference. Let us explore the possibilities.

First, we have tuning—the only adjustment for selectivity provided in most receivers. Obviously, tuning can deal only with interference, differing appreciably in wave-length from the desired signals; if carried too far distortion results—of small moment in telegraphy, but fatal in the case of telephony. A little distortion of speech may not prevent the acquisition of information from that speech, but spoils the effect of readings, recitations, dramatic recitals, etc., and ruins music absolutely. Our resources in tuning include single, double, or multiple circuit adjustment for both wave-length and coupling, and such devices as rejectors (drains, wave-traps, etc.) and filters, which all depend on differences of wave-length. Suppose, however, that the interference is so near to the required signals in wave-length, or the damping is so great, or the distance from the receiver so little that it is utterly impossible to tune it out; need we abandon hope? Not a bit of it! If the jamming can be reduced (by tuning) to a smaller strength than the desired signals, we may still suffer

annoyance from it, especially in telephony, so we weaken the coupling of the tuner, when the interference disappears first, leaving us free to amplify the received signals, if required, far more effectively, than when mixed with other noises. This remedy is denied us in the case of a set worked near oscillation point, as loosening the coupling in such a case produces instability. On the other hand, if the interference is stronger than the desired message we have to seek other means of elimination. One simple but effective device is the balanced crystal detector. The carborundum-steel combination is not sensitive to weak signals unless a certain potential is applied, but strong signals come in well with considerably less applied potential, or even none at all. Advantage is taken of this to use two such detectors in parallel, but connected in opposite directions. One is rendered as sensitive as possible, the other less so; then signals stronger than a certain critical value pass equally through both branches, thus producing no resultant current in the phones, whilst weaker signals are rectified by the sensitive crystal, not affecting the insensitive one at all. Thus, the originally weak impulses affect the telephones, whilst the strong signals wipe themselves out. The weaker the signals required the more can the second crystal approach the sensitive point, when any jamming or atmospherics giving rise to higher pressures are either completely silenced or weakened to a point far below those sought. There are always plenty of "experts" ready (and eager) to tell one that balanced crystals are "no good," absolute wash-out, etc., etc., but on careful enquiry one finds that these experts have never tried them, and do not understand the action, nor even what classes of interference they are designed to cut out. It remains that this device, coupled with intelligent handling, will cut out jamming that tuning will not touch. Balanced two and three-electrode valves have been tried, but are less satisfactory than the crystals, being less sensitive, and involving greater complication. The Marconi Co. not only fitted balanced crystals to ships' sets, but up to fairly recently employed the system (with H.F. and L.F. valves) in commercial transatlantic reception. If balanced valves are not a practical proposition, there is another property of a valve which can be turned to account—and is utilised in the great majority of commercial stations of to-day. This property is known as "limiting," but goes further than its name would suggest. The original idea was so to adjust a valve that the required signals carried it to saturation; then any stronger impulses on the control electrode could not produce a greater change in anode current than these signals; hence the possible resultant strength of any incoming impulses can be *limited* to that of the signals desired; in other words, strong signals do not appear in the recording or reproducing instrument at greater strength than any selected weak signals. Fate, in this instance is kind; on trying out such arrangement of valves, in nearly all cases a similar effect to the balanced crystals is found, and the selected messages give stronger response than either originally stronger or weaker signals. The limiting valve may precede any H.F. valves, may also act as H.F. amplifier, or may also act as detector. In practice, it is found that the last is quite convenient and simplifies the adjustment considerably. It should be noted that valves with pure metal filaments only —*i.e.*, not dull emitters—are flexible enough for use in this service; it is necessary to have the saturation point under minute control, and the emission characteristics of the various dull emitters are not sufficiently controllable.

In the case of continuous waves, sharper tuning is possible, but greater care is needed in the application of limiting or balancing, or these may not be effective. However, further control is possible in this case than in damped waves. Looser coupling to the aerial is possible, and if a separate heterodyne is used (as it should be), the adjustment of its strength at the point of application to equal exactly the strength of the required signals ensures that all other signals, whether stronger or weaker originally, are weaker in the phones.

It is not suggested that the methods outlined above will deal with all forms and degrees of interference ("wipe out" will defy the most frantic efforts, for example), but a full use of these effects will go far fowards minimising the nuisance.

In Search of a Real Receiver.

By H. ANDREWES, B.Sc., A.C.G.I.

The writer being dissatisfied with the conventional system of receiving, and at the same time being strongly opposed to the use of freak circuits, gives below his experiences of a circuit which embodies interesting refinement.

I THINK it would be as well if I made my object in writing this clear at the start. I have *not* discovered a new circuit which is to revolutionise the whole science. Again, I am *not* going to describe how I can receive all the B.B.C. stations on a 2-ft. loop. I merely wish to clear up in my own mind, and I hope in the minds of some of my readers, what we are really out for when we try and design our receiver. I am going to look at the problem solely from one point of view, namely, that of the active transmitter.

Theoretical Considerations.

Now I think most transmitting licence holders will agree with me that when "all's said and done," if you want to work "DX" regularly and get some useful reports, the average "freak" circuit is not much good.* That may, of course, be a sweeping statement to make, but still I believe it to be true.

In the case of the man who only has a reception licence of course it may be different, he has more time to prevent his circuit from "spilling over"; but when you never know when the H.T. supply won't fail or your smoothing condensers start flying about the room, well—then I do like to know that, at any rate, my receiver will function.

Let us, therefore, take the standard circuit, which we were all brought up on, and see what its deficiencies are and whether we can remedy them.

The circuit I refer to is, of course, the single-valve regenerative. Now, first of all, about regeneration. They can say what they like at 2LO, but there will always be, in my humble opinion, much too much difference between a regenerative and a non-regenerative receiver to make it worth while considering the abolition from our receiver of regeneration. Of course we then come up against the "oscillator" difficulty (not broadcast, of course, but listening to yanks!). Let us draw a veil.

Turning now to the design of our receiver. We will assume that we set up a single-valve regenerative which works. I do not propose to go into considerations of dead-end in coils, the size of reaction coils, etc., as I am convinced that there are no rules in that game at all and one can only go on till one is lucky! Now with this circuit we shall get good results, but there are several disadvantages.

Firstly, our signals are not very loud. This may be easily remedied by adding a stage of L.F. amplification. This does not in anyway complicate the working of the set, and brings previously faint signals up to a reasonable strength.

Secondly, reaction is not very easy to control, and considerable practice is needed in the manipulation of the circuit.

Next let us consider H.F. amplification. According to the text-books we are told that, by using H.F. amplification, we can bring in stations which would otherwise never be heard. With this statement we all agree *provided* our H.F. amplifier amplifies. This, then, is our first serious problem. Can we get satisfactory H.F. amplification?

As regards waves within and above the broadcast band, the answer is unhesitatingly yes, but below 300 metres I think the argument starts.

With a view to satisfying himself on the subject the author carried out a number of experiments. In all the tests "tuned anode" H.F. was used, as in practice it gave better results than transformers. It was then found that down to about 150 metres good H.F. amplification could be obtained, but that in the region of 100 or 120 metres very slight increase in signal strength was obtained by adding one H.F. valve. This is presumably due to the methods at present

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* The author of course does not include the Supersonic amplifier in this category, as it is *the* way out if you can afford it.

used, and there is no doubt that the great need at the present time is the invention of an H.F. amplifier which really does amplify at 100 metres and below.

From the results obtained above it was decided to incorporate one stage of H.F. amplification, as there is no doubt that, even though we may get no appreciable amplification on 100 metres, we do gain considerably in selectivity.

As regards the actual method, variometer tuned anode is to be preferred, as by reducing the capacity across the tuned anode coil we increase the E.M.F. (up to a certain point, of course), which is transferred to the grid of the detector valve. It will also be noticed that tuning is not quite so sharp, view of sensitiveness and selectivity it is very good. But I think most people, even after several years, will agree that it is not easy to work when one is searching for a station of a considerable band of wavelengths. Now for this circuit to work successfully it must be kept only just oscillating, as then it is most sensitive, and also the two circuits, namely, the grid and anode circuits of the H.F. valve, must be exactly in tune. We find, therefore, that our whole trouble is really the control of regeneration. As a rule a reaction coil is used to control regeneration, but this is never satisfactory, as when the coupling is altered to reduce (or increase) reaction the wave-length to which the grid circuit is tuned is inevitably

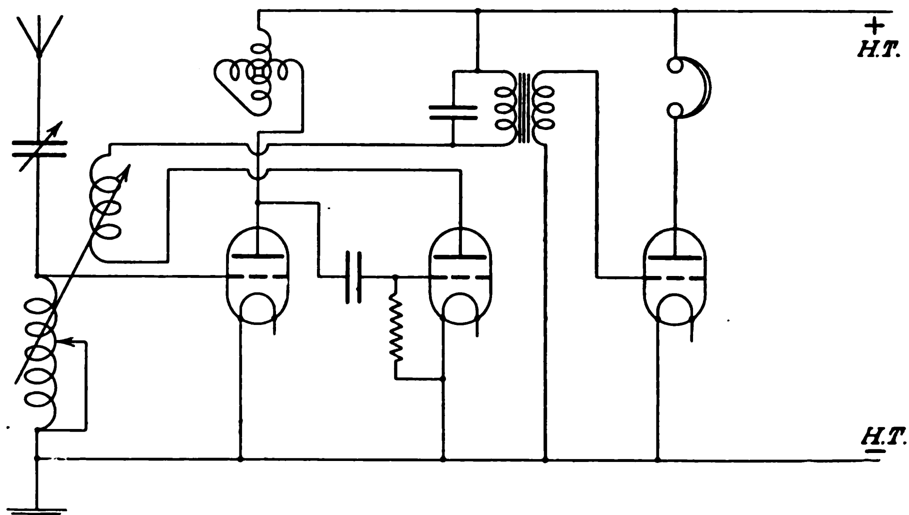


Fig. 1.—The conventional tuned anode and note magnifier circuit which forms the basis of the new arrangement

and also, owing to the shape of the variometer, anode tuning is easier near the zero of the scale, as the anode tails off much more gradually than does a variable condenser.

Let us now consider the circuit as far as we have got. It will be, presumably, something like Fig. 1.

In this case we placed the reaction coil in the anode circuit of the detector so that when the coupling is sufficient the detector is "feeding back" into the grid circuit of the H.F. valve, and the constants of both valve circuits will affect regeneration. This circuit is used very largely at the present time, and there is no doubt from the point of charged, so that a signal, such as faint telephony, takes quite an appreciable time to tune in.

Now in any oscillatory valve circuit there are in general three main ways of controlling regeneration :—(*a*) magnetically ; (*b*) electrostatically ; (*c*) by increasing the losses. I think (*a*) is the most commonly used at the present time, but it has the disadvantages alluded to above ; (*b*) has been used to quite a considerable extent, but the author does not like this method as one must inevitably by-pass a little energy from the grid of the first valve, and, secondly, it has all the disadvantages of de-tuning which are so

disastrous in the case of magnetic control.

There is another method of control which, perhaps, should be mentioned here, namely, control by filament temperature. It is not, I think, a method which is very widely used. But in order to give everything a chance this method was experimented with, but with very poor results. It was found that one of three things happened with this method. Either (*a*) one turned down, so to speak, the signal with the filament of the valve ; (*b*) the valve started and stopped oscillating with a violent " plop " ; or (*c*) one obtained the desired state, either just oscillating or just not oscillating, depending, of course, on whether one was receiving 'phone or C.W., but that things were very unstable. This is a state of things which one might reasonably expect, because there is no doubt that, unless one can afford 120-amp.-hour accumulators or take very considerable precautions with filament rheostat (carbon ones being, of course, particularly prone to variation of resistance with temperature), an absolutely constant supply of filament juice is difficult to obtain. A very good demonstration of slight variations of filament voltage, inevitable even with large accumulators, may be obtained by setting up such a circuit on the " Multivibrateur," a circuit for producing audio-frequency oscillation with two triodes. In this circuit the frequency will be found to slowly alter all the time owing to slight changes in the filament temperature, due to variations in the supply even when large accumulators are used.

We now come to the last method of control, namely, by introducing losses. It is well known that in the mathematical analysis of an oscillatory circuit consisting of inductance capacity and resistance, if the value of the resistance is above a certain limiting value, with a given E.M.F., no oscillations will be produced. Here, then, we have an excellent method of controlling the oscillatory tendencies of circuit. By introducing resistance into the grid circuit of the H.F. valve we can bring the valve to any desired state, either just oscillating or just off the point where oscillations commence. The practice of this method is not, perhaps, quite so simple as the theory, as we at once come up against a snag in designing our resistance. In order that the method may be effective the resistance must, of course, be (*a*) continuously variable ; (*b*) absolutely non-inductive up to frequency of, say, 3×10^6 cycles ; (*c*) noiseless in action ; (*d*) capable of fine control. A large number of experiments were made to find a suitable resistance. First of all, a non-inductively wound wire resistance was tried, having, of course, a sliding cutout, but this, although sufficiently non-inductive, was found to be too noisy in action and also the adjustment was not fine enough. Next a filament resistance of the compressed carbon type was tried. This was very much more successful. It was found to be quite fairly silent, to have good control, but unfortunately the maximum value was found to be not quite high enough (about 40 ohms). Apart from this defect this resistance worked very well. Various " home-brewed " resistances were then tried. These were made by dissecting a variable grid-leak of the compression type and filling it with various carbon mixtures. At first powdered carbon microphone granules, powdered graphite, etc., were tried, but these all proved very unstable and noisy. Stove polish was then tried, this consisting of graphite presumably mixed with some oily substance to give it a semi-solid consistency. Unexpectedly, this proved very effective, as quite a big variation of resistance was obtained (from 15–20 ohms to about 70 or 80 ohms), and it was quite silent in action. Unfortunately this resistance did not prove very consistent, but this was due, I think, largely to the design of the compression " gear " being unsuitable.

Turning now to the circuit itself, as we have successfully eliminated the reaction coil it is now possible to use a variometer in the grid-circuit of H.F. valve as well as in the anode circuit. By doing this it is again possible to increase materially signal strength, as dead end is eliminated on very short wave-lengths, and over the whole range of one's set, say 90–600 metres, it is possible to use a small series aerial condenser and a large inductance. In the author's case this resulted in quite a considerable increase in signal strength on distant broadcast stations. We now have a circuit as in Fig. 2. By using a well-designed variometer, as A.T.I., it was found possible with a 500-$\mu\mu$F. A.T.C. to cover the whole range required (90–600) with a series

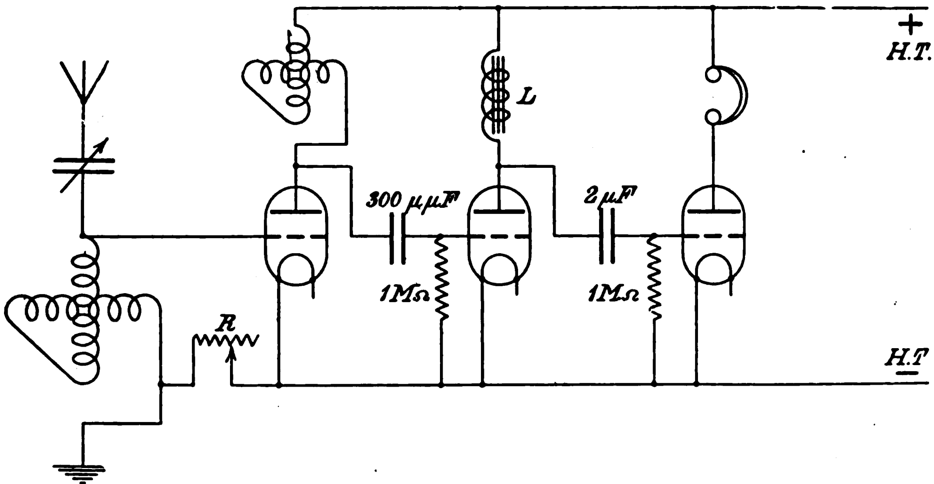


Fig. 2.—The final circuit embodying "resistance control" and a choke-coupled amplifier.

condenser. It should be pointed out here, I think, to the experimenter that this circuit does not, as a rule, work straight off as with this method of reaction control a considerable amount of juggling with H.T. and L.T. may have to be done to bring the control within the range of the resistance; but, then, how dull our lives would be if everything we tried worked first time! One other gadget might be mentioned in connection with receivers. It has probably been the experience of many of us to burn out L.F. transformers—an expensive pastime. It occurred to the author to try choke-capacity L.F. for a change, and this was found to be very effective. As a choke the secondary of a "Ford" coil was used, with a 2-μF. "Mansbridge" as an intervalve condenser. This gave quite as much amplification as a 25s. transformer, and, if anything, improved the quality of speech. This seems a much cheaper method of amplification, as the supply of "Ford" coils is never likely to run out and almost "any old condenser" will do.

In conclusion, the author hopes, if he hasn't assisted anyone, at least he may raise a discussion, as resistance control is really worth trying.

The New French Official Regulations for Wireless Stations.

give below a summary of the new French regulations which should be of great interest when compared with those obtaining in this country.

THE following are the main provisions of the official regulations governing the operation of wireless receiving and transmitting stations in France.

Stations are divided into two main categories: (I) Receiving, and (II) Transmitting, which are again subdivided into various classes.

I.—Receiving Stations.

There are three classes of these :

(1) Receivers for the reception and distribution of broadcast information at no charge to the general public. These are not subject to any tax.

(2) Receivers installed for public auditions (*i.e.*, places where the public are admitted on payment), including apparatus installed at restaurants, public halls, cinemas, etc. These will be subject to an annual tax, varying with the population of the district in which they are situated, the tax being 50 fr. for a commune of less than 25,000 inhabitants, 100 fr. for a commune of less than 100,000 inhabitants, and 200 fr. for a commune containing more than 100,000 inhabitants.

(3) Receivers not installed for public or paying auditions (this class being equivalent to that granted a broadcast licence in Great Britain). The only charge is a registration fee of 1 fr. (for French citizens), which may be paid at any Post Office.

In all cases receiving apparatus must not send out any waves capable of interfering with neighbouring stations.

II.—Transmitting Stations.

These are divided into five classes.

(1) Fixed stations for private use. The power input of these is limited to 400 watts, and they may use a band of wave-lengths from 150 to 200 metres. Groups of such stations (as, for example, a number established for the purpose of intercommunication between the head offices of a works and the residences of its officials, outlying parts of the works, and intercommunication stations in towns, are restricted to 100 watts input and a band of wave-lengths from 125 to 150, and the height of the aerial must not exceed 30 metres.

(2) Portable stations and their corresponding fixed stations are limited to 400 watts and wave-lengths of from 150 to 180 metres. This regulation does not apply to existing stations established under International Convention, or under special Government regulations, under which their technical characteristics are specially defined.

(3) Radio-telephone stations transmitting items of news and general interest. Technical conditions of such stations may be specially determined by the Ministry of Posts and Telegraphs.

(4) Stations equipped for testing and scientific experiments. The technical characteristics of these are governed by the special nature of the proposed tests or experiments.

(5) Amateur stations. These are limited to 100 watts input, on 180 to 200 metres wave-length.

Stations of the third, fourth and fifth classes must not be used for personal or business communications.

Licences for transmitting stations can only be obtained by persons who hold an official certificate either as radio-telephonist or radio-telegraphist, or persons who employ a certificated operator. Examination for these certificates is held at the home of the candidate, for which he has to pay a fee of 15 fr. The test for an amateur is for capacity to send and receive sound signals in Morse code at a speed of eight words a minute, and other classes of applicant must be able to send and receive at the rate of fifteen words a minute. Candidates must also show a knowledge of customary telegraphic abbreviations, and must be able to regulate apparatus on three different wave-lengths. Candidates for certificates as radio-telephonists must show their capacity for sending and receiving speech, knowledge of radio-telephone procedure, and regulation of apparatus on three different wave-lengths. The law came into force on January 1 of this year, and all existing operators are given three months from that date in which to secure certificates.

Continuous wave transmission only is allowed, controlled or modulated by speech or musical sounds, and French only must be spoken or used, except by special permission of the authorities. Any special or unusual mode of transmission is strictly forbidden.

All transmitting stations in Classes (1) and (2) are subject to a licence fee of 100 fr. per kilowatt, and an annual tax of 40 fr. per watt. All other stations will pay a tax of 100 fr. per year per kilowatt, temporary stations paying in proportion to the time for which they are in operation.

A Valve Generator for Audible Frequencies.

By E. SIMEON.

Electrical oscillations at audible frequencies, or actual sound waves at high frequencies, are of considerable value in many experiments. Below will be found complete data for constructing a suitable oscillator.

THE instrument described below was made to give a wide range of musical notes, as pure and loud as possible, and which would not vary appreciably in pitch and amplitude at any given setting. Such an apparatus is very useful in making and testing low-frequency apparatus, such as transformers, loud speakers or oscillographs, or recording apparatus.

With the circuit of Fig. 2 one can obtain at least one musical note. It consists of an oscillating valve circuit in which the coils have sufficient inductance to give a frequency well within the audible range. The ends of the primary winding (used as the reaction coil) must, of course, be joined the right way round to produce oscillations. A small fixed condenser across the secondary will lower the note produced.

To increase the volume the H.T. may be raised to 200 volts with an "R" type valve, and one or two grid cells may be necessary. Using this voltage and a loud speaker the note should be easily audible 50 yards away.

Using a small power valve such as the O-10-B does not seem to increase the volume appreciably.

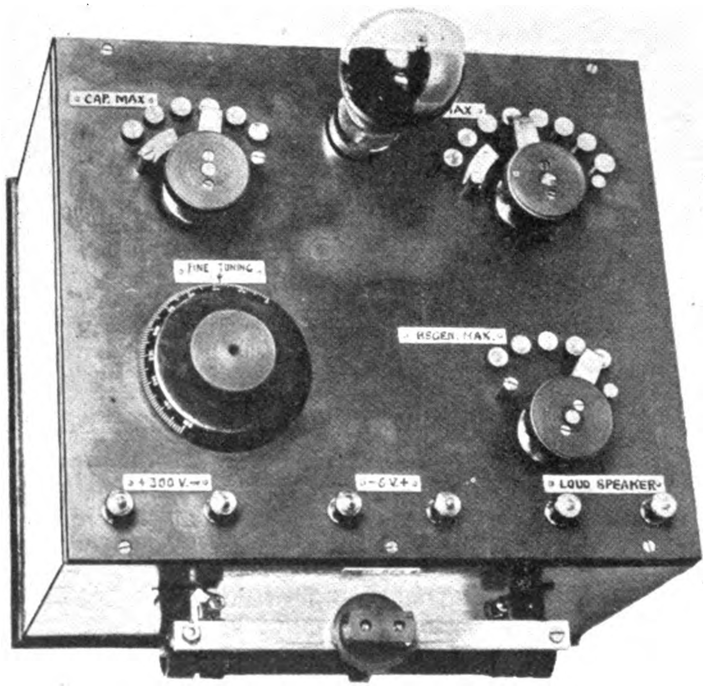


Fig. 1.—A general view of the oscillator showing various controls.

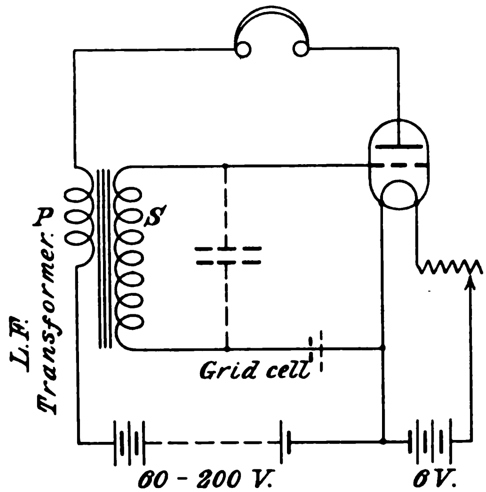


Fig. 2—An oscillator employing an inter-valve transformer.

Small alterations in frequency are caused by altering the filament temperature, etc. The frequency falls if through any cause the anode current increases.

The instrument shown in the photographs is an elaboration of the foregoing, to give frequencies from about 170 to 10,000 per second, which corresponds to a wave-length of 30,000 metres and might be tuned in on a long-wave radio receiver.

Constructional Details.

The tuning condenser has a value of from 0 to ·006 μF. This consists of a ·001 μF. variable air condenser and three fixed condensers, which are introduced by the switch shown in Fig. 3. This arrangement is easier to make and capable of finer adjustment

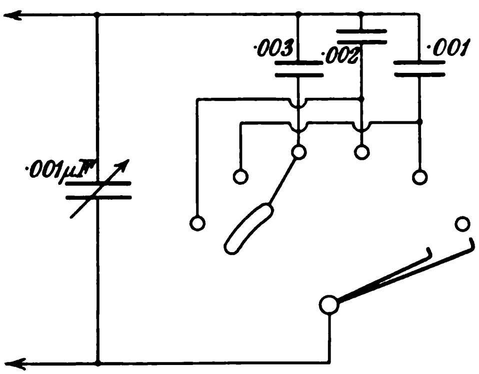


Fig. 3—Arrangement of variable condensers.

than a single large variable condenser. A larger parallel capacity should not be used, or the volume will be reduced considerably.

If desired, a sliding iron core might be used in the inductance, in which case the condenser could be dispensed with and variation in frequency between the tappings obtained by pulling the core in and out.

The two windings are wound in separate slots on an ebonite bobbin 2½ ins. diameter. The slot for the tuning coil is 1¼ ins. wide, wound with about ½ lb. of No. 44 D.S.C. wire, with six tappings. The reaction coil is contained in a slot ⅝ in. wide, and consists of 2,500 turns of No. 36 wire, tapped at 400,

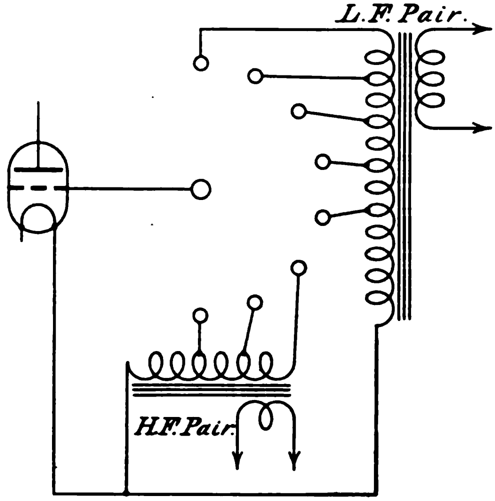


Fig. 4—Connections of tuning coils to switch.

1,100 and 2,500 turns. An open core of iron wires ¾ in. diameter is inserted through both windings.

The ends of the bobbin should be about ⅜ in. wide, so that small studs, to which the tappings are soldered, may be screwed into them as the coil is wound.

The following method of taking tappings from the tuning coil was used :—The reaction winding having been put on and the condenser completed, sufficient turns were wound to give, by trial, the highest note in the range. This gives the first tapping. On shunting this by the maximum capacity a much lower note was given. Turns were then added till the latter note was again obtained, but with the condenser at zero. This gives the second tapping. Then on

adjusting the condenser to its maximum capacity a lower note again was obtained, more wire wound on, and so on until the lowest note required was given. For very low notes the number of turns increases rapidly, and the coil becomes bulky, besides introducing another effect. It was found that when a large number of turns were wound on the first few sections would not work. For the highest frequencies a separate and smaller pair of coils were therefore made, spaced from and at right angles to the larger pair. Both tuning coils are, however, introduced by the same switch (see Fig. 4). The two reaction coils are put in circuit by another similar switch.

The insulation should be good, particularly between the ends of layers. If a small part of the winding becomes shorted the oscillations will probably cease entirely, due to damping caused by induced currents flowing in the closed circuit formed. It is not, however, necessary or desirable to use shellac or wax, which would cause trouble if the coils had to be rewound for any cause.

The few tappings on the reaction coil cannot very well be omitted. It was found that if a medium-sized reaction coil were used on all frequencies it was insufficient to give full strength on low notes, while on high ones it had a choke effect preventing

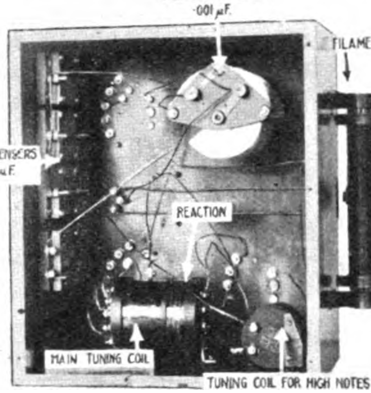


Fig. 5—Showing the arrangement of the oscillator coils and condensers.

the frequency rising beyond its natural frequency.

Spade Tuning.

Although the system of tuning by eddy current variation is well known to every experimenter, little practical information seems to be available, and we give below data for the construction of suitable plates.

VERY few experimenters seem to make use of this very simple and inexpensive method of tuning. Essentially it consists of a copper spade which is moved over the face of a slab coil, causing a variation of wave-length.

The action is due to the eddy currents set up in the spade by the high-frequency currents in the coil. The currents in the spade are in the opposite sense to those in the coil, and hence the self-inductance of the whole system is reduced, owing to the mutual induction between the spade and coil currents. The same phenomenon is met with when the secondary of a transformer is short-circuited. The inductance of the primary is destroyed.

A secondary effect is that the self-capacity of the coil is increased. This, of course, affects the wave-length oppositely, but reduces the effect of the inductance change very slightly. It is too small to be of any importance.

To obtain the maximum effect, the induced currents must be as large as possible. Hence the spade has to be of low resistance. The best material is soft copper sheet, about 20 S.W.G.

The tuning is remarkably sharp, especially when a little reaction is used, and perfect

stability is assured by connecting the spades to earth. The efficiency is at least as good as the parallel condenser, and will be much greater with good design.

The coils used should be of the slab type, of which there are several good makes. By means of a small fixed condenser in parallel with the coil the initial maximum wavelength is obtained. The spade is then made to move over the coil face, as close up to it as possible. As the coil is covered, the wavelength will decrease. On broadcast wavelengths the variation will be 100 to 200 metres, according to the type of coil and closeness of spade to its face. On higher wave-lengths the variation will increase, but not quite proportionately.

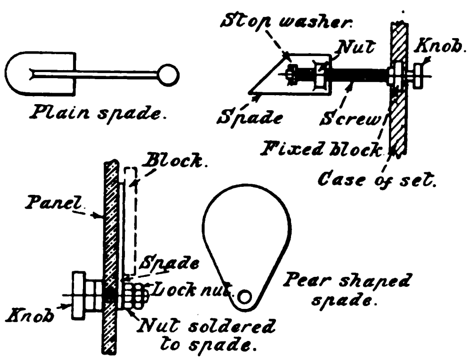


Fig. 1—Details of three forms of "spades."

The plates may be moved in a variety of ways. A well-known two-valve receiver uses a direct pull on rods attached to the plates. A three-valve of the same make has a quick thread screw rotated by a knob. The plate is fixed to a nut moving on the screw. Another method is to use a pear-shaped plate, the apex being drilled and secured with two nuts to a spindle on which is the operating knob. The latter is, perhaps, the most convenient method. These three are shown in Fig. 1.

Straight-line tuning can be obtained by suitably shaping the spade. The actual outline is best determined by experiment, but a rough idea of it is given in Fig. 2.

The coils may be fixed in position, or may be made interchangeable for any wavelength. They are best mounted in ebonite blocks, but this is beyond the capabilities of the average tool-kit. A very satisfactory substitute is available, however. Some hard wood, 3-16th in. thick, is soaked in paraffin wax and scraped clean. It is then cut up into suitable squares, say of 3-in. side. If the diameter of the largest coil exceeds 2 ins., then a larger block will be better. A

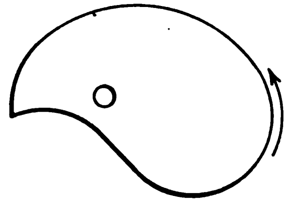


Fig. 2—Form of spade to give straight line tuning.

hole is cut through the wood, centrally, of such a diameter as to admit the coil, and two small recesses are cut out from it, as shown in full lines in Fig. 3. On one face of the block is screwed a $\frac{1}{8}$-in. ebonite plate, with two contact studs placed so that their nuts fit the recesses and clear the coil and the wood. Round-headed 4 B.A. screws, about $\frac{1}{2}$ in. long, are suitable. The coil is then inserted and the ends soldered to the studs. Good cotton wool packing is used to hold the coil in position. Wax is not recommended, as it increases the self-capacity of the coil, causing losses and broadening the tuning. It is also advisable to melt off any superfluous wax already on the coil, as too much is often used to keep the turns in place.

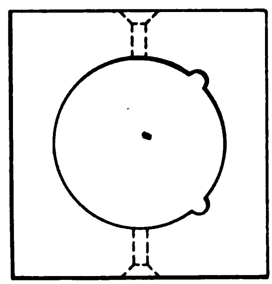


Fig. 3—A coil former for use with the system.

The coil should then be covered on the back with some thin stiff card, glued and pinned on. A thin sheet of ebonite is better, and can be screwed on with fine, short, countersunk screws.

When using card care should be taken that the spade does not rub on it too hard and cut it. Ebonite will stand this rubbing

without harm. As the coil should be packed to come right up against the thin back, this is a point to be watched (Fig. 4).

The mounting of the blocks has, of course, to be adapted to circumstances. If an interchangeable system is to be used a pair of guides should be made of stiff brass, about ¼ in. wide, and fixed to the back of the panel at such a distance apart that the block will be a fairly tight fit. Contact with the studs is made by a couple of springs fixed to an ebonite strip, which may support the lower ends of the guides and also act as a block rest. The supporting panel may be of wood, as it is insulated from the coil, and the spade has no electrical connection with the circuit. The idea is illustrated in Fig. 5.

If thin plates are used on both sides of the block, and a couple of narrow strips of ebonite are screwed on two opposite edges, then the guides themselves may be used to

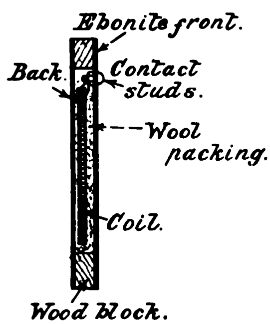


Fig. 4—Showing how the coil should be packed.

make the contacts with a couple of flat studs. In this case the two recesses in the circle cut out of the block are dispensed with for two holes drilled as shown by the dotted lines in Fig. 3. A groove for the nut holding the stud should also be cut as indicated, so that it shall not touch the wood. This method can be adopted if the guides are properly insulated from the wood panel. On the whole, the first method given is preferable.

Other methods to suit given conditions may be devised, and the idea can be extended to a plate moving between two coils which are set close together concentrically, or even with plates moving over the outer faces as well. With a series parallel switch a very large wave-length variation may be obtained. In this case it is advisable to fit a vernier adjustment to the spade control.

When two or three tuned circuits are to be used the coils may all be mounted in one block, spaced, say, 2 ins. apart. Then

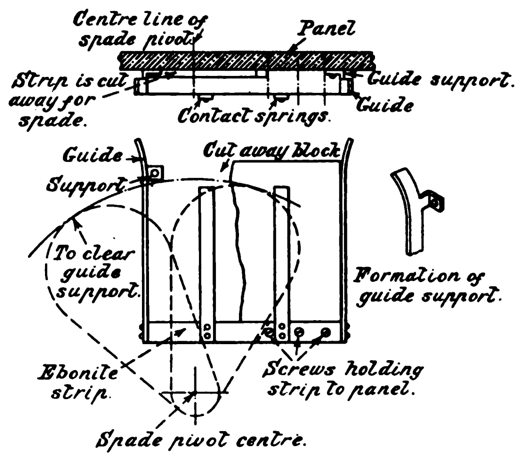


Fig. 5—Arrangement for mounting the "blocks."

the operation of changing from one wave-length range to another is very much simplified.

Sufficient has been said to show that there is a wide field for experiments with this tuning system, and any time spent on it will not be wasted.

A Correction.

In the March issue of EXPERIMENTAL WIRELESS the term $-\frac{2L}{C}$ was omitted from the equation at the bottom of the second column on page 319. It is thought, however, that the omission was so obvious as to cause no confusion to our readers.

Filter Circuits in Radio-Telegraphy.

By Dr. N. W. McLACHLAN, M.I.E.E., F.Inst.P.

The subject of selectivity is one of the greatest problems in radio engineering, but is nevertheless one to which the amateur experimenter may well give his attention. Before doing so a sound knowledge of the principles involved are necessary, and the following article should be of great value.

Introduction.

It is well known that various components of a radio broadcasting system possess the property of selectivity. So far as the tuned or oscillatory circuits are concerned selectivity is imperative to minimise jamming, but when telephones, loud speakers, iron-cored transformers and the like are concerned, selectivity is decidedly deleterious. Going a step further, and touching on the question of a high degree of reaction, it can be shown that the effect of the selectivity

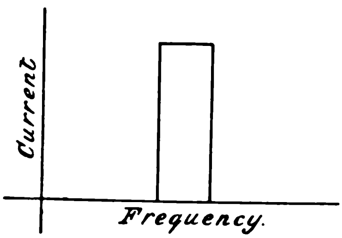


Fig. 1.—Showing relation of current to frequency.

concomitant with this phenomenon curtails the higher tones in telephony and spoils the quality of speech and music. In the present article the intention is to deal with selective circuits in a somewhat different way, but more particularly with their application to the reception of continuous wave telegraphy. When one invades the band of wave-lengths associated with the radio communication services between Europe and America, duly armed with *ordinary* receiving apparatus, the first impression is one of chaos. Indeed, the satisfactory reception of some of the long-wave American stations, say Marion (WSO), seems well-nigh impossible through the jamming from Stavanger (LCM), Nauen (POZ), etc. This lenghere selectivity reigns supreme and an blocksent type of circuit is quite useless. of the i the design of satisfactory circuits for continuous operation requires considerable skill and experience. In order to present as concise an idea as possible on the above matter we shall deal with the salient features of filter circuits which are used for commercial work.

Circuits in Cascade.

Imagine a variable-frequency continuous-wave generator, *e.g.*, a valve generator loosely coupled to an oscillatory circuit whose condenser is set to a certain reading, but can be altered if desired. If the frequency of the generator is varied through the resonance frequency of the oscillatory circuit, and the steady E.M.F. induced in this circuit by the fundamental oscillation of the generator is constant, the relationship between the frequency and the steady r.m.s. current in the oscillatory circuit is in the well-known form of a resonance curve (see Fig. 1). Let the resonance frequency be 30,000 cycles per second, and the root mean square current in the circuit be 1 unit for simplicity. Then at a frequency of 29,700 or 30,300 cycles, the current will be less than that at 30,000 cycles. The ratio of the two values of current depends on the high-frequency resistance of the circuit at 30,000 cycles. The greater the resistance, the greater the ratio of the current at 29,700 to that at 30,000 cycles, *i.e.*, the flatter the resonance or selectivity curve. Moreover, the object to be attained to secure good selectivity is to construct a circuit in which the ratio of L/R (inductance/resistance) is as large as possible. Put in another way, if the size of the inductance is fixed, the resistance at high frequencies must be as small as possible. The resistance is chiefly due to the inductance coil when air condensers are used. In high-frequency work air condensers are generally used, although on long wave-lengths good mica condensers

are serviceable. Particular care must be exercised to avoid dust between the plates of air condensers, badly soldered joints and faulty contact to the moving vanes. In long-wave radio circuits, to obtain as small a resistance as possible, the usual practice is to employ stranded cable, the individual strands generally being insulated by silk. The best wire is made up in multiples of 3, *i.e.*, a cable of 81×36 S.W.G. D.S.C. would have $[(3 \times 3) \times 3] \times 3$ strands. Assuming that the value of L/R is sufficiently large, the selectivity curve of the circuit will have a fairly sharp peak. One circuit in itself is generally insufficient to give the required degree of selectivity, so that it is essential to loosely couple another circuit to it. Granting for the moment that the *only coupling between the circuits is electro-magnetic*, the selectivity of the combination is greatly enhanced over that possessed by one alone (see Fig. 2). Some figures will make this clearer. We have already premised that the current at a resonance of 30,000 cycles is unity, and we may assume that at 29,700 and 30,300 it is $\frac{1}{3}$. This is the current in the first tuned circuit. In the second tuned circuit the current will obviously be less by an amount depending on the degree of coupling, the resistances of the circuits and the selectivity. At a frequency of 30,000 cycles assume again for simplicity that the current is 1; then its value at 29,700 and 30,300 cycles will be $\frac{1}{3}$ of unity—neglecting the reduction due to loose coupling, whilst illustrating the principles involved—provided the current in the first circuit was the same at all frequencies. But the current at 29,700 and 30,300 cycles in the first circuit is only $\frac{1}{3}$, hence its magnitude in the second circuit is $\frac{1}{3} \times \frac{1}{3} = \frac{1}{9}$. Similarly at another frequency, if the current in the first circuit were 1-10th, that in the second circuit would be 1-100th. It will be evident now that the method of arriving at the current in the second circuit is to square that in the first circuit. In the case of three circuits the current at a given frequency in the first would be cubed to get that in the third, *e.g.*, at 29,700 cycles the current in the third would be 1-27th. In the foregoing discussion we have disregarded the reduction of the currents in the various circuits due to the effect of loose coupling. Moreover, if the ratio of the maximum currents in the first and second and the second and third circuits is $\frac{1}{4}$, due to loose coupling, the current in the third circuit at 29,700 cycles would be $\frac{1}{3} \times (\frac{1}{3} \times \frac{1}{4}) \times (\frac{1}{3} \times \frac{1}{4}) =$ 1-432nd the maximum current in the first circuit.

A curve plotted in this manner for several circuits *loosely coupled* in cascade is a guide to the overall selectivity of the system for a series of *steady* currents of different frequencies (see Fig. 3).* The arrangement is known as a filter, since the undesirable steady frequencies on either side of the frequency it is desired to receive are filtered out. It is essential to take precautions to prevent the current in the first circuit inducing into those which follow; similarly for the second circuit and so on, *i.e.*, the couplings must be solely from 1 to 2, 2 to 3, 3 to 4, etc. The customary procedure is to house the various units in earthed screening boxes, the coils within the boxes being arranged astatically if desired. Coupling between adjacent units is obtained by means of small coils. The contiguous portions of consecutive circuits are such that condenser action (sometimes termed electrostatic coupling) is the least possible. In present radio practice there is a limit to the number of circuits which can be cascaded. The limit is fixed by (1) the amount of variation of wave-length at the transmitter;

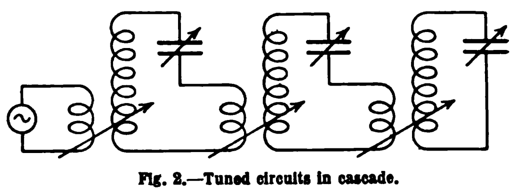


Fig. 2.—Tuned circuits in cascade.

(2) the speed of sending. The first limiting cause is fairly obvious, because a variation in wave-length from 30,000 to 29,700 cycles on a four-circuit filter system of the above nature would result in a reduction of signal strength from normal value to $\frac{1}{3} \times \frac{1}{3} \times \frac{1}{3} \times \frac{1}{3} =$ 1-81st of that value. As this figure refers to voltage or current reduction, and the energy in the telephone receiver is proportional to the square of the voltage, the energy would have been reduced to 1-81st $\times$ 1-81st = 1-6,561st of its normal value. This would obviously be an impossible

* When the currents are increasing or decreasing (transients) the case is different.

state of affairs. Either a modified circuit or a much more constant wave-length, or both, would have to be obtained. In modern valve transmitting plant the usual practice is to employ a master oscillator, this being coupled *via* one or more banks of amplifying valves to the aerial. By this means the variation in frequency can be confined to extremely narrow limits. In practice the receiving circuits should be arranged so that the top of the selectivity curve is approximately flat. This means that the received strengths of all waves covered by the flat top will be approximately equal.

Telegraphic Modulation.

The second source of limitation is far from obvious, but an example may make the matter clear. Consider a series of dots to be sent by a radio station. When the current in

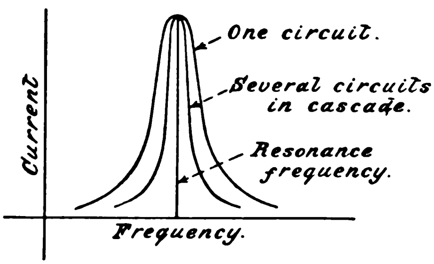


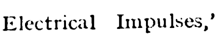
Fig. 3.—Resonance curves for various circuits.

the aerial is plotted against time the result is a series of high-frequency oscillations lasting for the duration of a dot, these being separated by blank periods of equal length, in which there are no oscillations. This can be viewed as a class of modulation of the carrier or main wave, the wave form of the modulation being rectangular. In postulating this wave-form, the building-up period at the beginning of a dot and the decay period at the end have been disregarded for simplicity, *i.e.*, the transients at the transmitter have been assumed to be of sufficiently short duration to be neglected. Imagine the usual form of valve oscillator with a switch in the anode circuit so that the supply from the battery can be made and broken. When the switch is closed for the duration of a dot the D.C. voltage on the circuit is equal to that of the supply from the battery and is constant. When the switch is opened the D.C. voltage on the circuit is zero. If these opening and closing periods correspond with the dots and dashes of the Morse code the D.C. voltage wave form is a series of rectangles. Now a rectangular wave can be resolved mathematically, by aid of Fourier's theorem, into a sine wave of fundamental frequency equal to the frequency of the dots, and a series of harmonics, whose frequencies are integral multiples of the fundamental. For example, if there were 100 dots per second the frequencies of the various sine waves would be 100, 300, 500, 700, etc. Moreover, the transmitter can be considered to be modulated by a series of audio-frequencies having these values. The problem is different when the dots are interpolated by dashes and irregular spaces. Under these conditions the modulation is complex. This modulation, on regular dots, yields side frequencies with which we are so familiar in radio-telephony. In telephony on, say, 430 metres, *i.e.*, 700,000 cycles, a side frequency corresponding to an audio-frequency of 700 cycles is only 1-10th per cent. variation from the fundamental, whereas on a 10,000-metre wave, *i.e.*, 30,000 cycles, it is 2·5 per cent., or twenty-five times as much. With a circuit of average selectivity, the side frequencies of 700,000+700 and 700,000−700 cycles would be received almost as strongly as the fundamental, whereas in the long-wave circuit there would be a considerable reduction in the strength of these frequencies. In practice it is usually satisfactory to include the fundamental and the triple-frequency harmonic corresponding to a chain of dots.

The frequencies of the side tones depend on the speed of transmission. The higher the speed the greater the frequencies of those side tones which are of importance compared with the fundamental. If, however, the fundamental tone were reduced considerably owing to a high degree of selectivity at the receiver, the dots as heard or as recorded would be too short, since an adequate amount of energy would not be supplied at the receiver. Thus, at a given wavelength, to obtain dots of reasonable duration, the speed of transmission must not exceed a certain value. The ideal selectivity curve for steady oscillations—in accordance with our present mode of viewing the subject—is one with a flat top and vertical sides (see Fig. 3). In this way a range of frequencies on each side of the central frequency can be

received equally well. This provides for the proper reception of the side frequencies, which fall within the range covered by the flat top. Since for a given speed of sending the percentage variation of the side frequencies from the main frequency decreases with decrease in wave-length, the maximum speed of transmission with a filter circuit of given or constant percentage selectivity—*i.e.*, the width of the top of the filter expressed as a percentage of the main frequency—increases with decrease in wave-length. If the percentage is fixed the width of the top in cycles per second increases with the frequency, *i.e.*, with decrease in wave-length. The percentage in practice for any given speed of transmission decreases with decrease in wave-length. The width of the top is limited owing to the necessity for protection from atmospherics and jamming due to other stations. A filter having ideal characteristics would suppress all steady currents whose frequencies lay on either side of the range covered by the flat top. Taking a frequency of 30,000 cycles, if the width of the top were 200 cycles, all frequencies except those within the range 29,900 to 30,100 would be suppressed. In practice, however, the desired ideal cannot be attained. The top is not quite flat and the sides curve downwards in the well-known manner. The steepness of the curve depends, as we have already shown by the aid of simple calculations, upon the number of circuits arranged in cascade. The complete operation of filtering is not usually accomplished in the high-frequency circuits, and the customary practice is to pass the signals on to one or two high-frequency amplifying valves, and then, after being heterodyned, the signals are delivered to a rectifier.

In order to allow for strong atmospheric disturbances the length of the valve characteristic covered due to the signal should be short. Thus in the event of a strong atmospheric impulsing the system, none of the valves will reach their rectification or saturation points, and the signals, therefore, suffer the minimum of mutilation. In fact, distortionless *amplification** is just as essential here as it is in broadcasting. After rectification the signals are passed to a series of filter circuits tuned to the note or beat frequency. To take our example of 30,000 cycles again, assume that it is desirable to reduce to a negligible amount all frequencies except those within a band 50 cycles on either side of the central frequency of 30,000. This, as we have seen, is not done in the high-frequency filter, since it includes a band, say, 100 cycles on either side. Now 50 cycles is only ⅛ per cent. of 30,000, whereas if the beat tone were 2,500 the percentage variation is 2. It is easier to construct a note filter for a 2 per cent. variation than a H.F. filter to cope with a variation of ⅛ per cent. We have merely mentioned that filters are required to reduce all undesirable frequencies, but nothing was said regarding the origin of these aliens. They may be due to signals from a comparatively nearby station, *e.g.*, Nauen, Lyons, etc., or, worse still, they may be due to atmospherics. As explained in a recent article in EXPERIMENTAL WIRELESS†, an atmospheric can be resolved into a band or spectrum of continuous waves. Consider, for the sake of argument, the band of frequencies lying between 30,500 and 29,500 cycles, due to an atmospheric. If the width of the H.F. filter included this 1,000 cycle band, the ration of the strength of the atmospheric to the strength of the steady signal would be larger than that where the width of the filter was only 200 cycles, since in the latter case all the frequencies due to the atmospheric from 30,100 to 30,500 and 29,900 to 29,500 would be attenuated appreciably. Where the filtering process is extended after rectifying and heterodyning, the immunity from atmospheric interference is still further augmented. In the example just cited the width of the band at the note filter is assumed to be 100, *i.e.*, 50 cycles on each side of the central frequency. Thus the beats due to the atmospheric band frequencies which penetrate the H.F. filter —whose width we assume to be 200 cycles— will be suppressed by the audio-frequency

* In broadcasting, it is imperative to secure distortionless reception as well as distortionless amplification, *i.e.*, the high frequency circuits must have the minimum of effect on the "shape" of the signals. In telegraphy the use of filter circuits of low decrement distorts the signal badly. For example, a chain of dots of fairly square formation become a series of curves, thus : 

† N. W. McLachlan, "Electrical Impulses," February, 1924.

filter from 2,550 to 2,600 cycles, and from 2,450 to 2,400 cycles.

Summary.

We may sum up the preceding argument by the following cardinal points :—(1) Selectivity reduces the effect of jamming and of atmospherics by narrowing down the band of frequencies it is possible to receive to any appreciable degree. (2) Selectivity necessitates a constant wave-length at the transmitter. (3) The width of the receiving filter as measured in cycles per second must be sufficient to allow for (*a*) a slight variation in the frequency of the transmitter ; (*b*) the reception of the necessary side frequencies arising from the modulation at the transmitter when sending Morse characters.*

Fig. 4.—Showing wave form of modulation.

(4) Given a filter arrangement with a certain degree of selectivity to operate on a definite wave-length, there is a limit to the speed of transmission, *i.e.*, above a certain speed the signals received are illegible. The longer the wave-length the lower the limit of speed. (5) In practice the width of the filter band should be variable. When conditions are favourable, *i.e.*, jamming and X's are slight, the band of receivable frequencies can be widened and the speed of transmission increased. Under unfavourable conditions it is necessary to make the band narrower, and hence it is imperative to reduce the speed of transmission. (6) For a filter with a given range of reception, or width of the filter expressed as a percentage of the main wave, the shorter the wave-length the higher the speed of reception which is permissible. A similar argument applies at the transmitter, where it is obviously essential that the characters should be clear cut.

Atmospherics.

We may now take an alternative view of the problem of atmospherics and their effect on a receiving circuit. In reducing the effect of an atmospheric we are not concerned with the absolute magnitude of the disturbance, but with its value relative to that of the signal. For simplicity assume that we have a receiving circuit consisting of a loading inductance and an aerial tuned to the wave-length of the incoming signals, whose decrement can be varied at will. This might be accomplished by using some suitable and sensibly *stable* form of reactive circuit. Assume also that the wave form of the atmospheric is of the heavily damped sinusoidal variety whose frequency is much less than that of the signal*. Then there are two sources of E.M.F. in the aerial : (1) The undamped or continuous wave due to the signal ; (2) the highly damped wave of comparatively short duration, but large initial maximum value, due to the atmospheric. So far as reception is concerned, it is the E.M.F. across the inductance which counts. We can assume this to be applied to a rectifier or detector valve. The signal E.M.F. across the inductance increases as the decrement of the circuit is reduced (by reducing the resistance), since the current through the inductance is augmented. In fact, the *steady* signal E.M.F. across the inductance is inversely proportional to the decrement. Thus, if the E.M.F. with a decrement of 0·1 $\left[= \frac{R}{2fL}\right]$ were 0·001 volts, that with a decrement of 0·01, obtained, say, by reducing the resistance of the loading coil would be 0·01 volts, provided, of course, that the current had reached a steady value. During the initial and final epochs of a Morse character, when the current in the receiver is growing and decaying, the E.M.F. across the inductance is not inversely proportional to the decrement. It is during such periods, when the signal current falls short of its maximum value, that the atmo-

* In general the modulation is due to the dots and dashes of the Morse code—not merely a sequence of regular dots. Owing to the initial and final transients accompanying the Morse characters at the transmitter the modulation is not absolutely square cut, but of the form shown in Fig. 4. This represents the letter u, and it is clear that the initial and final stages are a greater proportion of a dot than of a dash. Moreover, when a very narrow band filter is used at the receiver, the effective duration of a dot is curtailed appreciably, and the only characters of consequence are the dashes. The initial and final periods can, of course, be resolved into their spectra of frequencies.

* This is represented by the equation $e = Ee^{-at} \sin qt$.

spheric, if of suitable phase and magnitude, can be peculiarly offensive.

Taking the *assumed* atmospheric of damped sine wave form, this causes E.M.F.'s of two different frequencies across the loading coil. One E.M.F. has the same frequency and damping as the atmospheric, and is known as the "forced" E.M.F., the other E.M.F. has the same frequency and damping as the aerial, and is known as the "free" E.M.F. When the atmospheric frequency is very different from that of the signal, it is only the free E.M.F.—due to the circuit oscillating at its own natural frequency—which need be considered. The first or initial maximum of this E.M.F. is almost independent of the damping of the aerial for the wave-lengths and decrements employed in practice. After attaining its initial maximum, the free oscillation due to the atmospheric dies away in accordance with the decrement of the aerial circuit. Moreover the atmospheric will have substantially the same initial amplitude in the aerial loading coil for a decrement of 0·1 as for one of 0·005. In the former case it will die away much more rapidly than in the latter, where it will be appreciably persistent. Superficially it would appear, therefore, that owing to the persistence of the atmospheric a circuit of low decrement would accentuate rather than mitigate the disturbance. In making this statement we have overlooked the effect of the low decrement aerial on the signal E.M.F. across the loading coil. With a decrement of 0·005, the *steady* signal E.M.F., which would follow the usual building-up period (this also is prolonged by reduction in decrement, and therefore a diminution in the speed of transmission is entailed), would be twenty times that with a decrement of 0·1, whereas the atmospheric E.M.F. would be equal in both cases. Thus the vector sum or difference in E.M.F. between the signal and the atmospheric increases in favour of the signal with decrease in decrement. It is this difference with which we are chiefly concerned in practice, both in reading and recording signals, since this is the voltage—in our particular case—applied to the grid of the rectifying valve or detector. As we pointed out above, this analysis is only valid for the steady state, and the ratio $\frac{\text{signal}}{\text{atmospheric}}$ is less when the current is growing.

When employing a circuit with low damping the result—as found from practical experience—is to weed out—relatively—all the minor atmospherics, since their E.M.F.'s are small in comparison with that of the signal, and the fact that they persist is, therefore, of little moment.

So far as the weaker atmospherics are concerned, suppose we have our aerial decrement as 0·1, and let us assume that the decrement as 0·1, with the result that the initial maximum voltage of the atmospheric is equal to that of the signal. Then the result will depend on the phases of the two E.M.F.'s. The worst case will occur when they oppose each other, for the effect will be almost to suppress the voltage applied to the rectifier for a short time. Now imagine the decrement to be 0·005. The signal will be twenty times the value of the atmospheric, and therefore the voltage applied to the rectifier will not be appreciably affected, even though the E.M.F. due to the atmospheric persists.

With a strong atmospheric the resultant voltage will depend on the ratio signal to atmospheric and upon their phase relations. During a dot, a dash or a space, the effect on the ear is reduced by employing circuits of low decrement. In recording, it is immaterial if the atmospheric and signal give augmented voltage during a dot or a dash when an instrument is used which functions between fixed stops. On the other hand, if

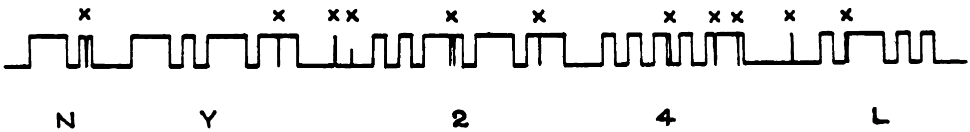


Fig. 5.—Sample of tape obtained from New Brunswick, U.S.A., (WII) with magnetic drum recorder. The rapidity of action of the instrument and the adjustment of the receiving circuit is such that the tape is not rendered illegible by atmospherics, automatic transmission taking place at 25 words per minute.

the superposition of the two yields an appreciable reduction in voltage the dot or dash is split or partially obliterated according to conditions. When a strong atmospheric comes during a space it yields a voltage which actuates the recording mechanism.

Using suitable high and low frequency filters arranged so that the decrements of the various component circuits are such that duration of the oscillation due to an atmospheric is short compared with that of a dot, it is possible to secure a legible record, provided the recorder responds very rapidly, and strong atmospherics are not too abundant. The appearance of the tape is of the form exhibited in Fig. 5. This is a reproduction of a portion of a message obtained from (WII) U.S.A., with the author's magnetic drum recorder.*

The question of atmospherics has been treated from two standpoints, *viz.*, (*a*) taking the spectrum of the atmospheric without reference to any particular wave form; (*b*) assuming the atmospheric to be a highly damped wave whose frequency is much lower than that of the signal. Both methods are instructive, and each has its merits on certain points. In practice the wave form of the atmospheric varies considerably and in many cases does not even resemble the simple shape we assumed. Furthermore, the effect in the receiver at any instant may be due not merely to a solitary atmospheric, but to a rapid succession of them, *i.e.*, the high-frequency oscillations in the receiver due to the various atmospherics are superposed on one another and on the signal. Under favourable conditions the atmospherics may appreciably annul each other. It is, however, the unfavourable conditions with which the radio engineer must cope.

The further reduction of atmospherics over and above that obtained with selector circuits of low decrement, which is possible with the aid of directional apparatus, has not been considered, as it is beyond the scope of the present article. In passing, we may state that to atmospherics of the damped sinoidal variety—and probably to other types—the only advantage of a single frame aerial lies in its directional properties.

Circuits of Low Decrement.

There is another aspect of the problem which can be treated, and one which is concomitant with high selectivity. When a train of electro-magnetic waves arrives at the receiver the currents in the various circuits do not attain their maxima values instantaneously. In this respect a comparison can be made with a motor car starting from rest. It cannot attain a speed of 30 miles per hour at once, since there is an acceleration period during which the speed gradually grows. The period of growth is due to the inertia of the car and the fact that a definite amount of energy must be supplied so that it can acquire a certain speed. The same reasoning applies to an electrical circuit. Electrical energy has to be added, and a certain time must elapse before the necessary condition is satisfied. The electrical circuit has a property which is equivalent to inertia, and this is associated with the inductance of the loading coil. The greater the ratio of the inductance to the resistance, the longer is the time taken for the oscillatory current to build up to its sensibly steady or maximum value. Moreover, if an incoming Morse dot is short enough, *i.e.*, the speed of transmission is sufficiently high, the current in a highly selective circuit would never attain a steady value. Consequently the apparent duration of the dot at the receiver would be very small, and in some cases almost imperceptible. But this is not the only side of the situation. When the incoming electric waves cease at the end of a dot, the currents in the receiving circuits do not stop suddenly, just in the same way as a motor car does not come to a standstill as soon as the engine is declutched and the brake applied. It moves on for a definite distance in virtue of the energy supplied during the initial acceleration period, or, more generally, in virtue of the kinetic energy due to its motion. Consider a circuit in which the ratio (inductance/resistance) is large, *i.e.*, the damping is small. On a long wave of, say, 20,000 metres, at a speed of 150 words per minute, the first of a chain of dots would scarcely be heard, because the current in the circuit would never reach its maximum value. At the end of the dot the current in the circuit would begin to decay, but would not be zero when the next dot started. The current would build up again, and by the end of this dot it might not attain its full value. There would be the

* See *Journal I.E.E.*, Aug., 1923.

usual decay period during the accompanying space, when the current would fall slightly in value. Thus the building up process would go on until the current approached its maximum value at the end of, say, the fifth dot. It would never be reduced to zero during the accompanying space, and its value during a space would be a fraction of its value at the termination of the preceding dot. The magnitude of the fraction would depend on the ratio (inductance/resistance). This phenomenon is readily obtained experimentally with the proper circuits, and is variously termed "hanging on," "ringing," "sustained" or "loud pedal effect." The latter terminology is almost self-explanatory, since it obviously refers to the effect obtained on a piano when the sustaining pedal is depressed continuously so that succeeding sounds merge together.

The phenomenon to which we have alluded is easier to obtain with several audio-frequency circuits in cascade than with high-frequency circuits. In making this statement it has been tacitly taken for granted that reaction is not employed either intentionally or accidentally. The well-known effect of reaction in dynamically reducing the resistance of an oscillatory circuit, and thereby enhancing its selectivity, can be employed to exhibit the phenomenon. The degree of reaction must, however, be under control, and it is essential that a slight variation in adjustment should not be accompanied by oscillation.

Finally, for satisfactory and continuous reception on a long-distance commercial service selectivity is indispensable, but the degree employed depends—amongst other things—on the conditions at the receiver, provided always that the circuits at the transmitter are sufficiently damped to give clear-cut transmission, *i.e.*, absence of appreciable sustained effect. With the low-resistance transmitting circuits employed in present day commercial radio, the initial and final stages of a character may be of importance at the higher speeds of transmission.

Suitable Valves for Grid-Absorption Modulation.

A popular method of modulating the output of a valve transmitter for telephony consists in shunting a control valve across the grid-coupling coil of the main oscillator valve, the plate of the modulator valve being connected to the upper end of the grid coil and the filament to the lower end. Microphone potentials from the usual type of microphone transformer are applied between grid and filament of the modulator valve. This circuit, which is sometimes referred to in the London district as "the 2OM circuit," depends for its successful operation largely on the use of suitable modulating valves. The ordinary R-valve gives quite good results as an absorption modulator up to powers of about 30 watts. We find, however, that low-impedance power-amplifier valves are particularly suitable for the purpose. Tests were made with the L.S.5 valve, which was found to be particularly excellent and to give much fuller control than R-valves. No doubt other low-impedance valves, such as the Western Electric, would give similar results.

When an L.S.5 is used its grid should be given a negative bias of at least 6 volts, and a positive bias on the anode of 15-20 volts seems to improve the modulation to a certain extent under some circumstances, though good results may be obtained without any D.C. potential on the anode of the modulator valve at all.

When using grid absorption control it is a good plan to tune the grid circuit either with a variable condenser or by using a variometer. The use of grid tuning gives a flexible control of the modulation, and usually renders any close coupling between the grid and anode circuits unnecessary, in order to maintain the set in oscillation.

The Use of Neon Tubes for Electrical Measurements.

By GERALD R. GARRATT (5CS).

The neon tube is receiving considerable attention at the present time and probably many more applications will be devised. As a voltage measurer it has much to commend it from the amateur's point of view and the following details should be of considerable use.

FOR some time past neon tubes have been used for the comparative measurement of high resistances, such as grid leaks, and also for the measurement of large capacities, but, as far as the author knows, they have not yet been used for the measurement of voltage.

Some time ago it was found necessary to measure the supply voltage of the author's transmitter, but it was not convenient to purchase a direct-reading instrument, partly because they are often inaccurate and partly on account of the price of a reliable meter.

Therefore, some other method had to be found, and the method finally adopted made use of one of the properties of neon tubes.

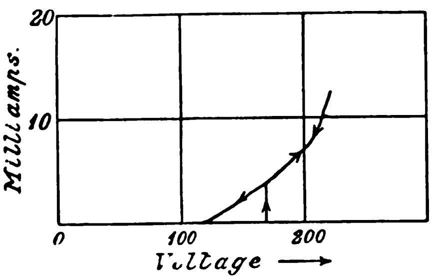


Fig. 1.—Typical characteristic of an "Osglim."

It might be mentioned that the neon tubes for this purpose should not contain the safety resistance embodied in the cap of the commercial type of lamp. This should either be removed, or a special tube purchased which contains no series safety resistance.

Since a recent article by Mr. E. H. Robinson has dealt extensively with the properties of neon tubes, only a brief explanation will be given here.

Fig. 1 shows the general form of the characteristic curve of a neon lamp. This curve shows that if the applied voltage is gradually increased from zero no current flows until a certain voltage is reached (the striking voltage), when the current suddenly jumps from zero to a few milliamps. The current increases slowly, with further increase of applied voltage, but when the voltage is gradually reduced the lamp continues to glow even when the striking value is passed, and the current does not fall to zero until the applied voltage is 15 or 20 volts below the striking voltage.

By use of this property it is possible to arrange the tube as a generator of oscillations. The most usual arrangement is shown in Fig. 2.

The current flows slowly through the high resistance, and slowly charges up the condenser. When the E.M.F. of the condenser reaches the striking point the lamp commences to glow, and continues to do so until the potential of the condenser falls to the extinguishing value. The condenser then recommences to charge, and the cycle is repeated.

The frequency of the flashes is controlled by the values of resistance, capacity, and voltage in use, and by the constants of the particular neon tube. It might be mentioned that different lamps, even of the same type, vary enormously as regards striking and extinguishing voltages, due probably to slight differences in the pressure of the gas within the tube.

It will be apparent that by reducing the values of resistance or capacity the frequency of the flashes can be caused to increase, and exactly the same effect will occur by increasing the value of the applied voltage.

In practice the frequency is variable from one flash in several minutes to the upper limits of audibility.

The range, however, with which we are concerned is what might be termed the "visible range"; that is, the range of frequencies which may be counted with absolute accuracy by the unaided eye. Up to 150 flashes a minute can be counted by the average man, but with a little practice this may be increased to 250 or more.

For the purposes of measurement of resistance, capacity, or voltage, it is essential that some apparatus of known values should be available. For instance, for the measurement of voltage it is essential that a supply of known voltage should be at hand with which to make a comparative measurement.

It is almost impossible to give even a rough list of values required for different purposes, as they vary so much with the tube in use. In the author's case, for the measurement of voltages from 300-2,000 volts, a G.E.C. "beehive" tube is used in conjunction with a 2-mfds. Mansbridge condenser and a few grid leaks—about 2 megohms for 300-900 volts, and about 4 megohms above this.

The apparatus is first standardised on the 240-volt D.C. mains (which should first be measured with an accurate meter, as in some districts the voltage varies considerably at different times of the day), and the number of flashes in a minute counted. Then the apparatus is applied to the unknown voltage and the number of flashes in a minute again counted.

Since the rate at which the condenser charges is directly proportional to the applied voltage, the number of flashes in a given period of tune is also proportional to the applied voltage, and thus the value of the unknown voltage may be easily obtained by working out a simple proportion.

It is rather surprising to notice how the number of flashes with given apparatus on a constant voltage will vary from day to day. This is due to the change in resistance of the "grid leak" with the humidity of the atmosphere. One particular cheap but widely advertised "constant grid leak" varied from ·7-3·8 megohms under ordinary working conditions from day to day! This variation also applies to some of the cheap anode resistances. A resistance stated to be 100,000 ohms will often vary from 80,000 to 160,000 ohms. Needless to say, this variation is not met with in the better types, which are specially protected against humidity changes.

Owing to the variation of the value of the resistance it is advisable to standardise the apparatus on a known voltage every time it is used, and to ensure absolute accuracy it is advisable to re-standardise the apparatus after the measurements in order to make certain that the resistance has not changed during the operations.

Normally, however, with reasonably good apparatus, no difference at all can be detected

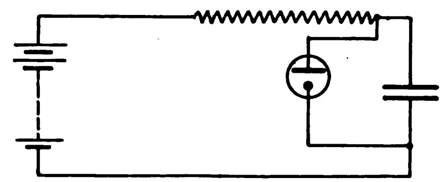


Fig. 2.—Circuit used for the generation of impulses.

and using high-class instruments no variation can be detected from day to day, even if the flashes are counted for several minutes. It is possibly unnecessary to point out that the accuracy attainable must depend to some extent on the time during which the flashes are counted.

At first I expected that the value of the resistance would vary with the current flowing through it, owing to a slight rise in temperature, but I have never been able to detect any error due to this cause. The reason is, of course, that the energy consumed is so small, usually about 1-100 watt.

The minuteness of the power consumed is one great advantage which this method of measurement possesses. Most high voltage meters require at least 5 milliamps for full scale deflection.

Exactly the same principle may be applied to the measurement of high values of capacity or resistance, provided that standards are available with which to compare the unknown values.

Electrostatic Transmitter Amplifier Circuits.

The two weak links in any broadcasting "chain" are undoubtedly the microphone and the telephone receiver. Considerable experimental work is now being conducted with an electrostatic microphone, with a view to improving the quality of speech and music, and we give some details of the special amplifiers which are necessary.

THE electrostatic transmitter, which was developed to a considerable extent by E. C. Wente some years ago, has been described on several occasions and considerable details may be found in the *Physical Review*. It would be somewhat redundant to deal with the actual transmitter at any considerable length, and our readers are, therefore, referred to the publications mentioned.

Fig. 1—Front view of the microphone showing wire gauze guard.

However, for the benefit of those who do not wish to investigate it very fully, we reproduce in Figs. 1 and 2 an illustration of the microphone which is a little more than half natural size. It consists essentially of a corrugated back plate which is at a distance of about 2 mils. from a tightly stretched steel diaphragm, which forms the second electrode of the condenser. The diaphragm is electrically connected with a metallic case, and also a wire gauze disc, which protects the diaphragm from damage. The leads from the microphone constitute a concentric cable in which the outer wire is connected to the diaphragm and the metallic case of the microphone, which are earthed.

The microphone is capable of giving very faithful reproduction, and a response curve is given in Fig. 3 for frequencies up to 5,000. It will be seen that this is substantially flat, and when it is remembered that the ear cannot appreciate an increase of some 300 per cent., the usefulness of the characteristic will be realised.

Owing to the comparative insensitiveness of the transmitter, a considerable number of stages of amplification has to be employed, and as the construction of a microphone of this description is not beyond the scope of many experimenters, it is thought that some details of a suitable amplifier will, therefore, be of value. The electrostatic transmitter has been perfected by the Western Electric Co., and we are indebted to them for the details of the amplifier circuits about to be described, and these, it is thought, will serve as a basis for experimental work. The operation of the instrument is probably well known, and consists essentially of connecting the condenser microphone in series with a high resistance and high voltage supply. Sound waves impinging upon the diaphragm cause the distance between the diaphragm and the back plate to vary, thereby altering the capacity fo the condenser, and causing potential variations to be set up across the high resistance. The actual amplifier employed can best be divided into two parts, the first part, comprising two stages, being shown in Fig. 4. The electrostatic transmitter is in series with a high resistance, and the applied potential is 220 volts. The potential variations set up across the resistance R1 are communicated to the grid of the first valve by means of a condenser C1, which serves to insulate the grid from the high voltage, a grid leak R2 being used, of course, to prevent the grid acquiring a high negative

potential. The first valve V1 is Western Electric 102D, and has an amplification factor of 30, and an anode impedance of about 50,000 ohms. This is resistance coupled to the second valve by a resistance R3 of about 100,000 ohms, the coupling condenser C2 being about 2 microfarads. The second valve is a Western Electric 101D, and is of much lower impedance. It will be noticed that the grid of this is biased by the battery B2 through the grid leak R4. Attention is here directed to the resistances R5 and R6 in the filament circuit of the valve V1. The filament of this valve normally works at 3 volts, but it will be noticed that it is supplied by a 6-volt battery. The function of the two resistances R5 and R6 is to cause a volt drop of some three volts, but the resistance is divided in each leg so as to provide the bias of about 1½ volts for the grid, which, of course, is communicated by means of the resistance R2. The second valve V2 is connected by means of an output transformer of the shell type to the input of the second amplifier. It will be noticed that two chokes L1 and L2 are included in the secondary of the output transformer, and are for the purpose of adjusting the impedance to that of the input transformer of the second

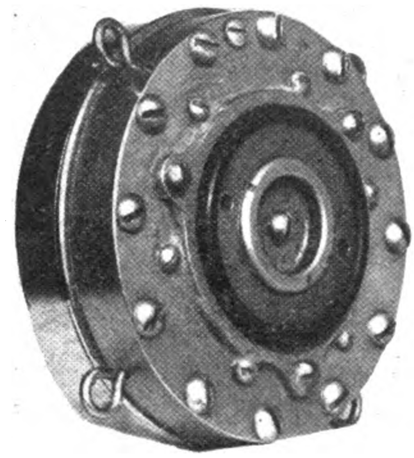


Fig. 2—Rear view of transmitter. Note the insulating ring between the two electrodes.

dard Western Electric gear. This amplifier, it may be mentioned, has been described in EXPERIMENTAL WIRELESS in connection with the article on simultaneous broadcasting, and details of this will be found in the

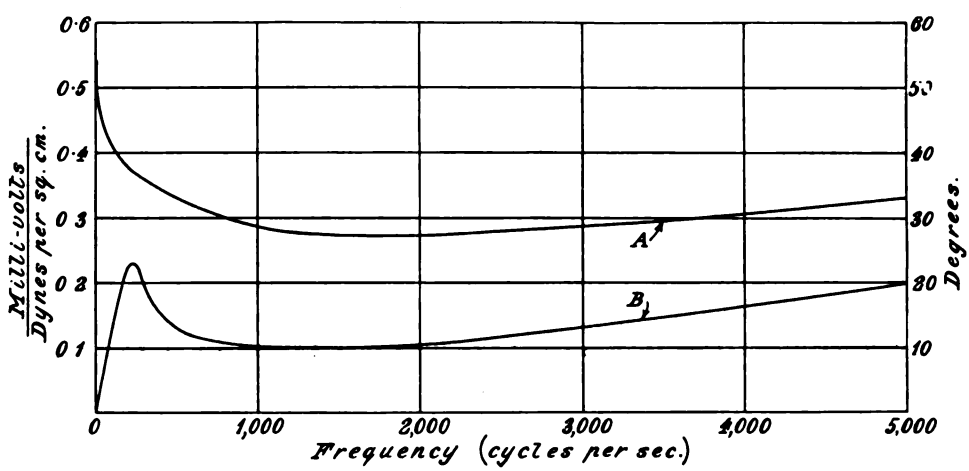


Fig. 3—Sensitivity characteristics of the microphone. A = Volts per unit of pressure. B = Phase lag of e.m.f. behind pressure.

amplifier, so as to obtain substantially constant working at all speech frequencies.

The second amplifier is of the three-valve impedance coupled variety with a differential input and output transformer, and is standard Western Electric gear. December issue on page 126. Although it will not be possible for the average experimenter to reproduce the amplifier shown in Fig. 5, a somewhat similar arrangement can easily be devised by substituting

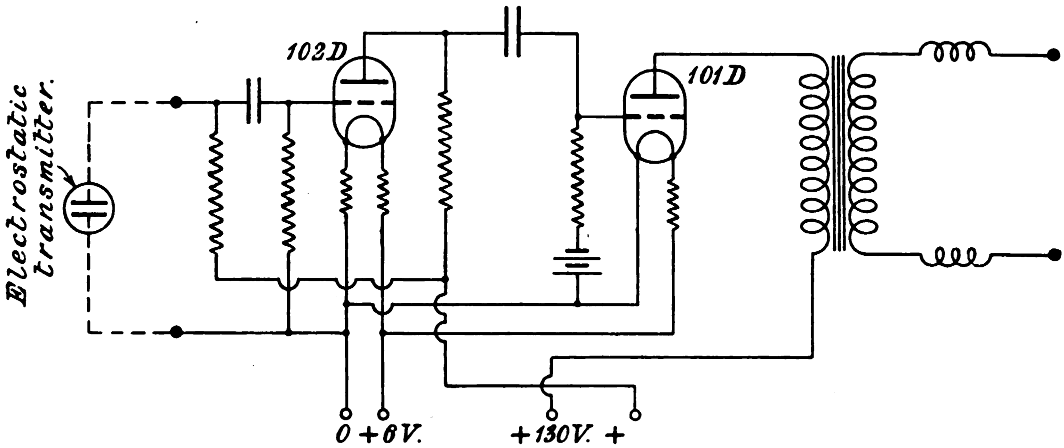


Fig. 4—The two-stage resistance coupled amplifier, showing the connection of the capacity microphone.

ordinary input and output transformers, adjusting the values of the various chokes and resistances to suit the valves available.

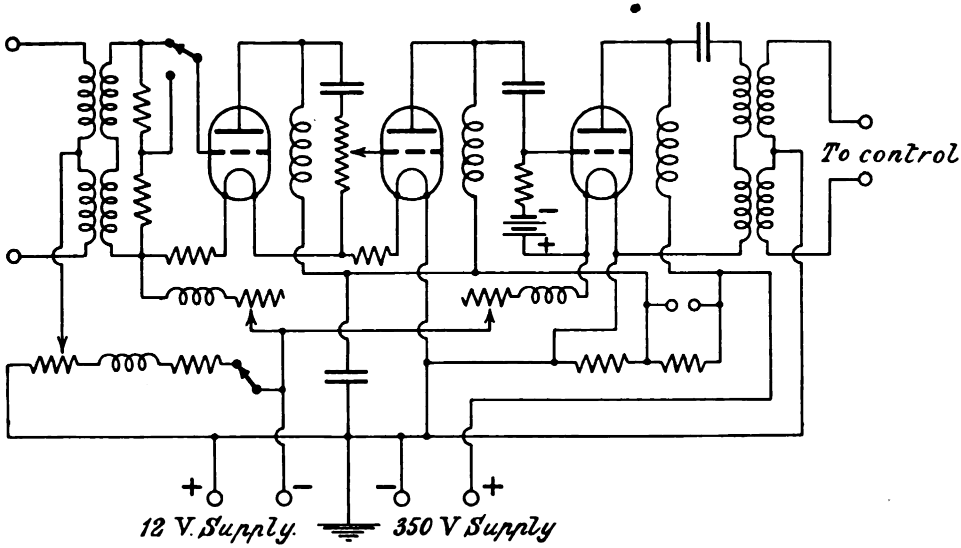


Fig. 5.—The arrangement of the three-stage impedance coupled amplifier, employing differential input and output transformers.

In passing, it may be mentioned that the electrostatic transmitter is now being used in some of the British Broadcasting Company's stations, and there is no doubt as to the excellency of the quality of speech and music which is obtainable, and it is certainly not beyond the scope of the amateur experimenter to work on similar lines.

A Two-stage Radio Frequency Amplifier.

As there has been a demand for details of a multistage radio frequency amplifier, we give below constructional data, together with the factors determining the design.

RADIO frequency amplification in a receiving system provides both increased signal strength and greater selectivity. More important, however, is the increase in signal strength since recent experiments show that equal selectivity in the final signals can be obtained at audio frequencies ; this, of course, refers to telegraphy only, selectivity of speech at audible frequencies being an obvious impossibility. If a square law is assumed for rectification, the importance of obtaining as large an initial potential as possible is clearly seen. This points to efficient radio frequency amplification, and should one stage be insufficient, it is vital to add additional stages until the desired potential can be given to the rectifier. Multistage amplification at audible frequencies is, comparatively, a simple matter, as intervalve transformers are substantially aperiodic at all audible frequencies ; in other words, no tuning is necessary, and no complications arise in the operation of the receiver. Amplification at high radio frequencies calls for tuned intervalve couplings, and each stage represents increased difficulty in operation. The use of resistances would render the amplifier aperiodic, but its

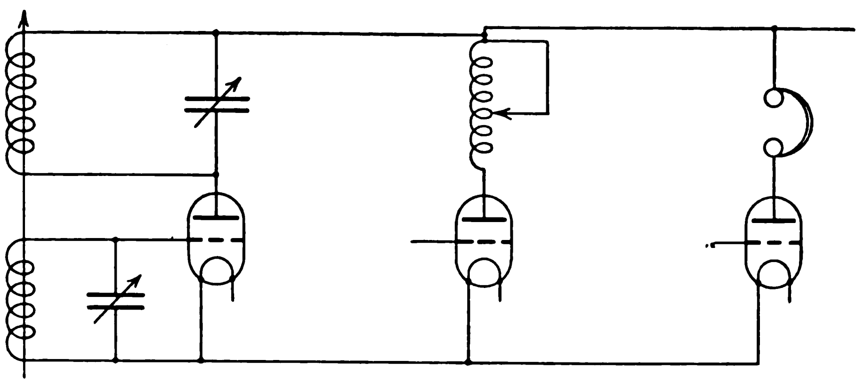


Fig. 1—Regeneration is here produced between the anode and grid circuits of the first valve.

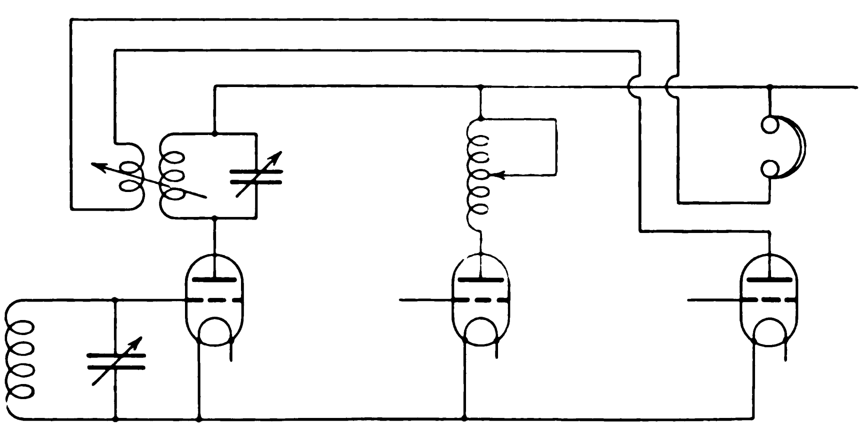


Fig. 2—Here regeneration is produced between the anode circuit of the first amplifier and the detector.

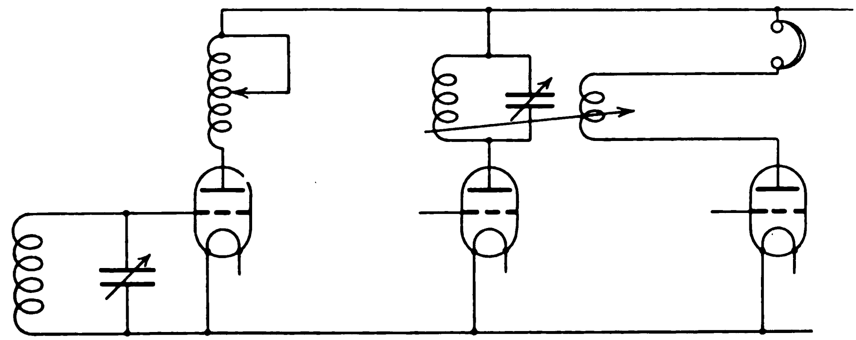


Fig. 3—In the arrangement adopted regeneration is produced between the anode circuit of the last two valves.

efficiency is limited by the inter-electrode capacities of the valves, which act as a shunt admittance. For this reason resistance coupling is normally only possible down to about 2,000 metres, or with special precautions and low capacity valves, down to about 1,000 metres.

The amateur usually requires to work on much shorter waves, and in addition, his receiver must be capable of rapid search. The object of the following notes is to enable him to build an instrument which will meet these requirements, and at the same time include only two critical adjustments, being, therefore, no more complicated than the familiar tuned anode receiver.

One obvious solution to the problem is the use of one critically tuned stage in conjunction with one or more semi-aperiodic

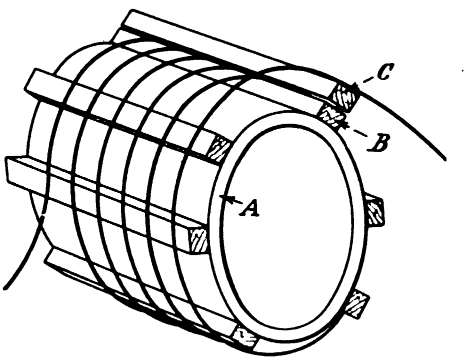


Fig. 4—A suitable method of coil construction for short waves.

stages. The input circuit of the first amplifier must, of course, be sharply tuned, but whether this is made the aerial circuit or coupled to it either loosely or tightly is left to the reader. The writer, however, would strongly advise a coupled aerial circuit. Whether the first amplifier is to be sharply tuned or semi-aperiodic must next be decided.

Assuming that both amplifying valves have similar charactertisics, the total amplification will be substantially the same with either arrangement of the coupling devices employed. Actual amplification, however, is not the only factor to be considered, selectivity and stability being almost of equal importance, while every effort should be made to minimise radiation when the receiver is in an oscillating condition. Reaction must obviously be employed in order to increase both selectivity and amplification, and also for the purpose of producing self-oscillation, unless, of course, a local heterodyne is used. For short waves this is really unnecessary, except for very critical work, and in any case would introduce another adjustment, thereby defeating the object of the design.

Obviously, then, there are three practical arrangements, these being shown diagrammatically in Figs. 1, 2, and 3 respectively. In Figs. 1 and 2, the input and anode circuits of the first valve are critically tuned and a regenerative effect is obtained between them or between the first and the anode circuit of the detector valve. Here there are three critical adjustments, the tuning of the two circuits and the coupling. The semi-aperiodic anode reactance, of course, only requires rough adjustment for different bands of frequencies. The arrangement of Fig. 3 is rather different, the input circuit of the first valve and the anode circuit of the second valve being critically tuned. The regenerative effect is obtained between the

anode circuit of the second amplifier and the anode circuit of the rectifier.

The circuit of Fig. 1 gives greater selectivity to the aerial circuit, but also results in greater radiation, since the first valve generates oscillations. If the circuit of Fig. 3 is employed, the input circuit is less selective, but the radiation from the aerial circuit is considerably reduced, so much, in fact, as to be quite unimportant. There are two other useful features of the circuit of Fig. 3. The first lies in the extreme stability of the whole system. The degree of regeneration is easily controlled, and there is no tendency for self oscillation to occur, resulting in an entire absence of overlap, provided, of course, that the various constants of the circuit are suitably chosen and that the apparatus is properly arranged. The other advantage of making the first anode circuit semi-aperiodic is appreciated when atmospherics and "mush" are strong. These both cause impact excitation of the aerial circuit, and if the anode circuit of the first valve is sharply resonant and near the point of oscillation, a strong atmospheric may cause the circuit to be "triggered." The use of a semi-aperiodic circuit obviously minimises this effect. The chief advantages of the circuit of Fig. 3 are, therefore, stability, ease of operation, and minimum of radiation, and it would seem that they fully justify the adoption of the system.

The Tuned Circuits.

Almost as important as the arrangement of the amplifier is the use of suitable tuned

Fig. 5—Position of plugs on short wave coil.

circuits. The amplifier is intended essentially for wave-lengths from about 200-1,000 metres, but the range is capable of extension more or less efficiently. There are only two resonant circuits, the grid filament of the first amplifier and the anode circuit of the second amplifier. The selectivity of the amplifier will be absolutely dependent upon the sharpness of resonance in these circuits, and accordingly they should be carefully considered and losses reduced to a minimum.

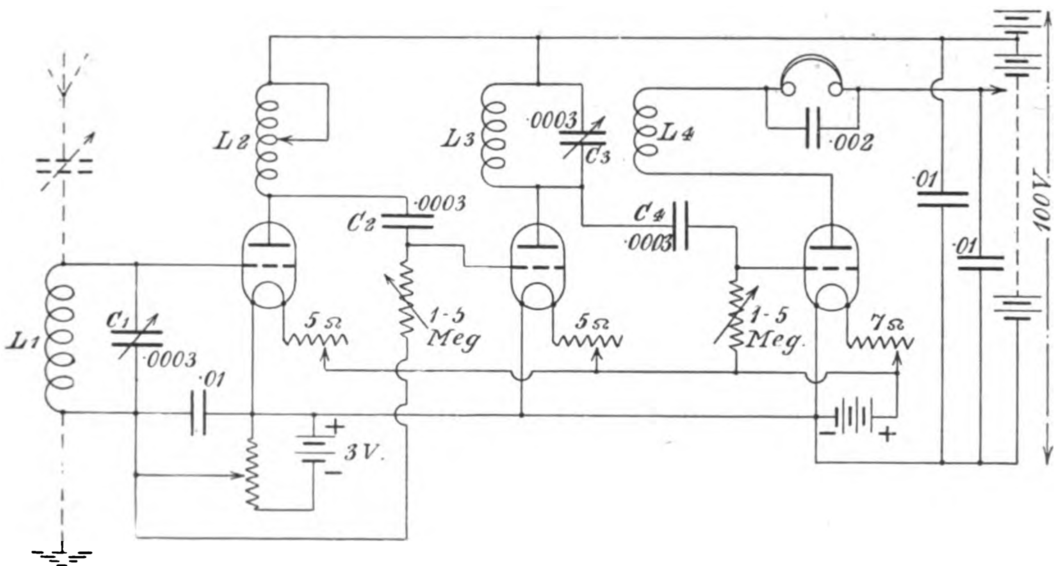


Fig 6 The circuit employed showing suitable valves for the components.

A large amount of literature has appeared recently on the subject of inductances, but it will be advisable to consider what type of inductance is best suited for this particular amplifier. The position can be summarised quite briefly when it is remembered that the requirements are sharpest resonance and maximum potentials across the tuned circuits. This obviously points to a circuit having a low high frequency resistance. Considering the inductance only, the high frequency resistance can be reduced by so constructing the coil that the self capacity and dielectric losses are made as small as possible. The actual gauge of wire used is not very important so far as ohmic resistance is concerned, but too large a size should not be used, as the capacity is increased and also it is not unlikely that eddy current losses may arise. Dielectric losses may be reduced by keeping any dielectric as far out of the field of the coil as possible.

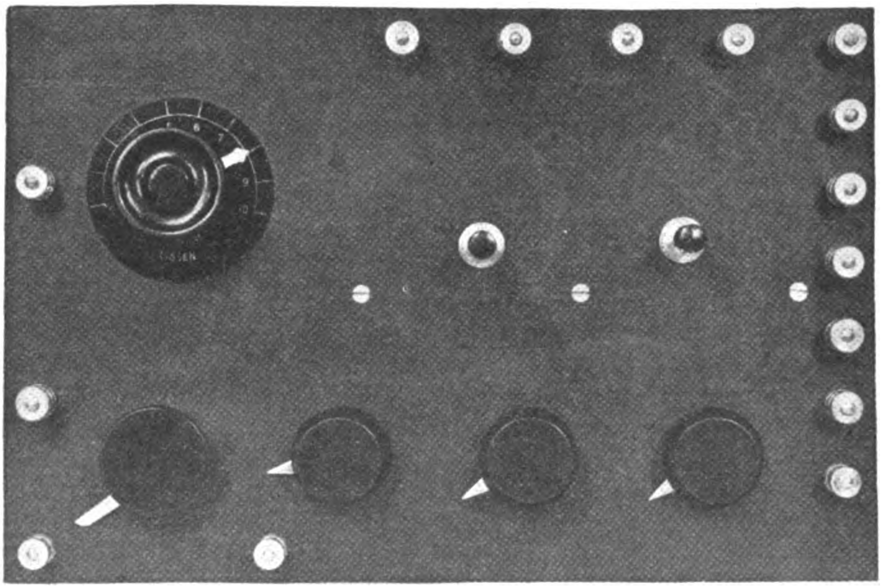


Fig. 7—Layout of front panel showing position of controls.

Short Wave Coils.

A very suitable form of coil construction is shown in Fig. 4, and this, or some modification of it, is preferred by the writer for frequencies of the order of 2,000 kilocycles. The former A should be either a rod or tube (preferably the latter) of some material having low losses, good hard wood usually being found superior to many grades of ebonite. The distance pieces B should be made as thin as possible to minimise the amount of dielectric in the field. These are fixed to the former, and the first layer of spaced wire is wound over them. Another series of distance pieces is then put in position, and the next layer is wound above them. This process is continued until a coil of the desired inductance is obtained. Coils of this description should be used for the input circuit, and the tuned anode circuit. The reaction coil in the anode circuit of the detector valve is not so important, and may take the form of the basket or honeycomb variety. When mounting the coils just described, the leads should on no account be brought to a two-pin plug ; neither should the first and last turns be brought near each other. A form of mounting on the lines of Fig. 5 is advisable.

The choice of the condenser used to tune the circuits is worthy of some consideration.

The chief requirements here are low ohmic resistance and low dielectric losses in the end plates. It is essential that all the plates of each section of a variable condenser are in efficient electrical connection. This is not always the case with cheap amateur assembled models, and may be responsible for considerable loss resulting in flat tuning. Another source of loss may occur through dust settling between the plates. The obvious remedy is to enclose the condensers in some suitable form of case.

The Layout of the Amplifier.

Enough has now been said to give the reader a good idea of the form of tuned circuits to employ, and it should be realised

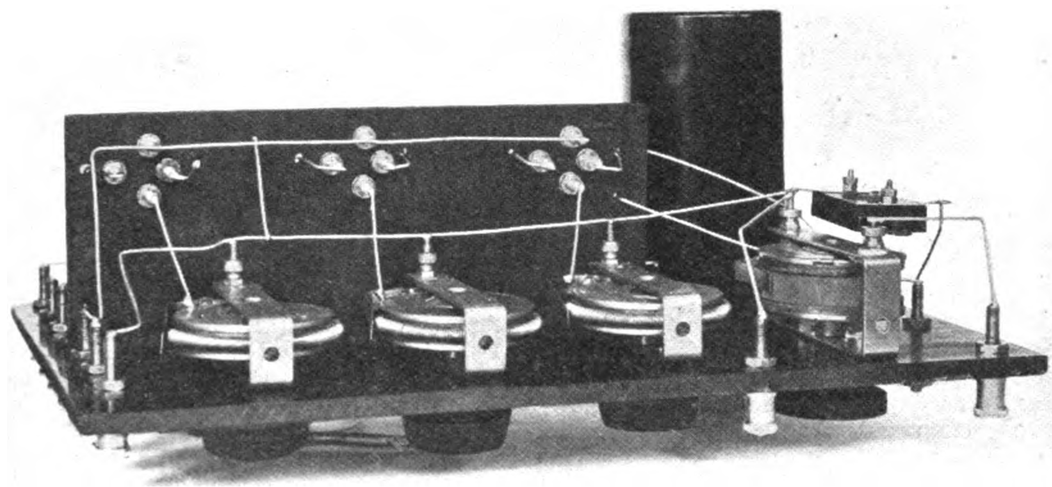


Fig. 8—Arrangement of wiring of the filament circuits beneath the valve panel.

that the success of the amplifier is largely dependent upon efficiency in this direction. Of equal importance, however, is the arrangement of the apparatus, and too much care cannot be exercised in carrying out the internal wiring. Stray capacities are the cause of more than half the inefficiencies which may arise. First of all, any appreciable capacity across the input circuit should be avoided. This means, of course, that the wire from the first grid to one input terminal should not be brought near to anything connected with the filament circuit. There is no objection to the wires from the input terminals being two or three inches long, or even running parallel, provided that they are not close together or near other parts of the circuit at widely different potentials. Here it is well to remember that capacity is inversely proportioned to distance. Thus, for example, an alteration of even half an inch in the position of a lead may make a very great difference. Anode and grid circuits must also be kept well apart, and, of course, any leads or apparatus forming part of them.

The foregoing points will be better understood, perhaps, by briefly examining the suggested layout which should be quite clear from the accompanying diagrams and illustrations. The complete circuit is shown in Fig. 6, and should need no further explanation. The values of the fixed condensers and resistances are given in the illustrations. The input to the amplifier is connected across the grid of the first valve, and the slider of a potentiometer, which may have a value of between 200 and 400 ohms. A fixed condenser of about ·01 μF. is placed across the part of the potentiometer included in the input circuit in order to by-pass the H.F. currents. The variable reactance (L2) in the anode circuit of the first valve should be one of the familiar tapped variety now on the market. That shown in the photograph was supplied by Lissen, Ltd., and has been found to func-

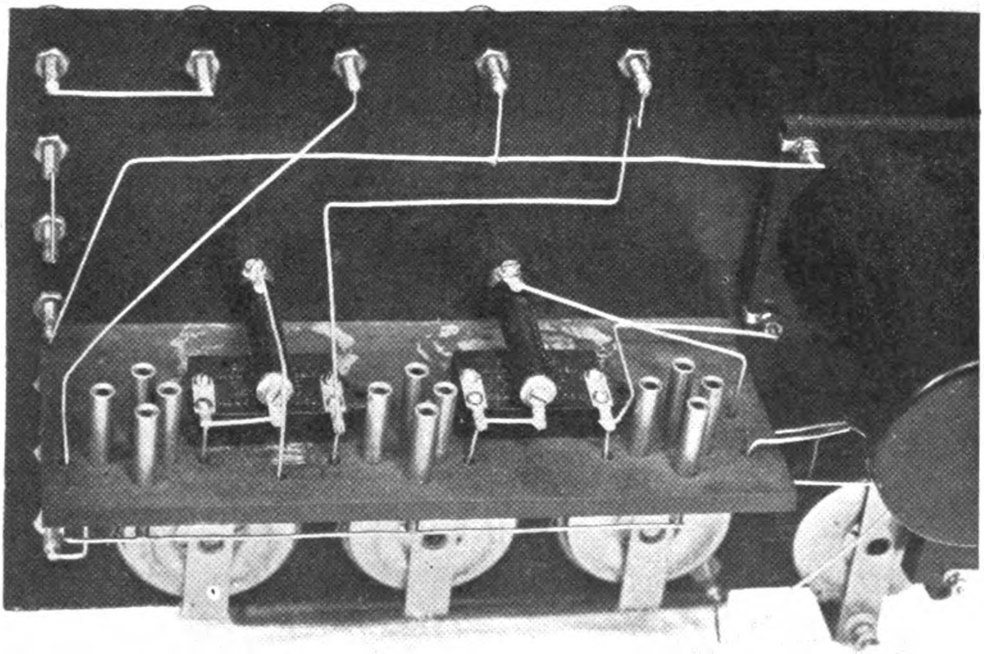


Fig. 9—Illustrating the short grid wires and arrangement of the anode leads to minimise capacity effects.

tion quite well. The coupling condenser C2 should be about ·0003 μF., and the grid leak of the order of 2 megohms. This is preferably of the variable type. The second grid condenser, C4, is for the purpose of providing cumulative rectification, and should be about ·0003 μF. The second grid leak should also be variable, and should be connected to the positive filament. The negative high tension should be taken to the *negative* filament, as this partially safeguards the valve filaments in the event of a short circuit between input and tuned anode circuits.

In carrying out the wiring, the leads should be made as short as possible without bringing them too close together, so as to minimise capacity effects. The actual wiring employed is best understood by referring to the two close-up views, and it is suggested that it should be adhered to fairly rigidly, since it results in very stable operation.

The panel shown in the photographs fits a 12×6 cabinet supplied by the Grafton Electric Co., Ltd., and is of a size most suited for the amplifier. Readers who construct the amplifier should adopt a similar arrangement of the apparatus, and should neither spread it out nor condense it to any considerable extent.

Adjustment of the Amplifier.

Little else need be said of the amplifier itself, but perhaps some notes on its adjustment will be of value. The best wave-length on which to test the amplifier is undoubtedly in the neighbourhood of 600 metres, on which ship stations of various strengths can be heard at almost any period of the day or night. First of all, select suitable coils for the input and tuned anode circuits, and tune the aerial approximately to 600 metres. Place the switch on the tapped reactance L2 in what is assumed to be the correct position, and then light the valve filaments and place the potentiometer in the minimum position so that the input circuit is connected directly to the negative side of the filament. Next brighten the first valve fairly fully, and make the second valve a little duller than the

first. Then tune in a station accurately on the tuned anode circuit, meanwhile varying the position of the switch on the first anode reactance until maximum strength is obtained. The aerial tuning should then be accurately adjusted. After the signal is properly tuned in, the valve filaments, potentiometer, grid leaks, and high tension should all be varied. No definite instruction can be given, but probably the maximum signals will be obtained with about 1-1·5 volt negative on the first grid, with a bright filament, and about 80-100 volts on the anode. The second valve may be a little less brilliant. These remarks refer, of course, to R type valves. The detector valve is preferably a soft one of the Dutch type, and will require a quite low anode voltage. Reaction should now be applied, and if the signals gradually increase and if self oscillation starts and stops without a loud click, the adjustments are correct. Should overlap be present, the filaments and anode voltage of the amplifier valves, and particularly the grid potentiometer and leaks should be varied until the points marking the starting and stopping of self-oscillation are coincident, or in other words, until overlap vanishes. If the amplifier is correctly built and adjusted, it should receive all British and Continental broadcasting stations without interference from each other. Tested on these wavelengths in the London district, all British stations were audible without applied reaction.

In conclusion, the reader is reminded that the efficient lower limit for any amplifier of the type just described is certainly not below about 200 metres, although, of course, it can be made to function at higher frequencies. For short waves, however, entirely different methods are adopted.

The Month's "DX."

Recorded by HUGH N. RYAN (5BV).

The increasing efficiency of amateur transmitters and receivers is resulting in the creation of many new long-distance records which are undoubtedly worthy of mention. It is proposed to record month by month work in this direction, and the Editor will be pleased to receive details for inclusion in these pages.

AT the time of writing it would appear that the season for transatlantic work is coming to an end, though it may yet last some time, and there is just a possibility that some intermittent work may continue right through the summer. Stations on this side are still working, of course, with the States and Canada, but the average strength of transatlantic signals has decreased very considerably, and it is not so easy to get into touch with the other side as it was a month ago.

On the other hand, it is, of course, possible that we are merely passing through a "bad period" as we have often done before, in which case we may expect things to become better before long. However, this does not seem likely, as a "bad period" usually begins fairly suddenly, and "when it *is* bad it's horrid," whereas at present signals are not really very bad, but appear just to be fading slowly away.

If we do lose touch with the other side during the summer, as most of us expect, it will be very interesting to see which of our men finishes the season with the greatest number of transatlantic "stations worked." Unless the season continues for a considerable time there is little doubt that the honour will lie between 2OD and 2KF, who are far ahead of any other stations.

At the time of writing 2OD has worked 32 and 2KF 29 Americans and Canadians, so we may expect a close finish. I believe 2NM and 2SH have each worked about 15, and 5KO 11. I have only been able to come "on the air" one morning a week, so have only managed to work 7.

During the month several more of our stations have been successful, 5LF, 6RY, and 5FS each having worked two Americans or Canadians, while 2WJ has worked 1XJ, 1XAH and 1BQ, and has been reported by 1BCF.

Of course, the original excitement of transatlantic work is now over, and now it is simply a matter of those who have not yet "got over" trying to do so, and those who have already been successful trying to get as good a "log" as possible before the end of the season. If touch is lost during the summer there will be the same keenness to be the first to resume communication next autumn.

The work which we have done so far on the very short waves has taught us a great deal about these waves, and caused us to modify our original views considerably. The only fact which cannot be contradicted is that we can cover much greater ranges on the same power on these short waves. At first I think most of us thought that there was some special virtue in the band from about 95 to 120, and that anywhere outside this band was nearly as bad as 200 metres. It has become evident that we were wrong, and that there is no such restricted band.

The present American theory is that, to obtain a good useful radiation the aerial must be operated below its fundamental wave-length, and therefore the only hard and fast dividing line is that wave-length.

It is unfortunate that we have not sufficient data to confirm or refute this theory, since nearly all our successful stations have "got over" either on the short wave only or on 200 metres only. As far as I know, only four stations (2OD, 2KF, 2NM and 5BV) have been received in the States on both waves, and the limited data available in these cases does not seem to confirm the theory of a definite dividing line at the fundamental wave of the aerial. In all three cases the same aerial was used for both waves, and in two cases approximately the same power. 2KF used slightly less power on 200 metres.

I will quote the actual figures in my own case only, as I am most familiar with them. My aerial has a fundamental wave of about 170 metres, and the upper wave transmissions were made on 200 metres. The aerial current was about 3½ amperes, and signals were apparently of quite good strength, though the wave was well above the fundamental.

With the same power on a wave well below the fundamental only 1 ampere was obtained at first, being later increased to 1·6. This "got over" quite well, but was still not reported as being strong until the wave-length was further reduced. I believe more or less similar figures apply to 2NM and 2KF.

These data, though very rough, seem to show that the "carrying" power of our signals depends upon shortness of wave alone, regardless of the size of our aerials. If the "sudden change at the fundamental wave" theory were true, it would not seem likely that any of our stations would have "got over" at all on the small power used, with wave-lengths above the aerial fundamental.

The above has little to do with "DX" reporting, but it concerns a subject of great importance to "DX," so perhaps my digression will be forgiven.

To get back to the reporting. In Europe most of the work has centred around the French stations, of whom there are now a considerable number working.

The work has not been of any great interest, apart from showing that very low power signals can still travel a long way on the despised 200 metres. 8SSU, of Bonn, another station run by members of the French Rhine Army, has been much in evidence, and has worked many British stations, including those as far North as 5SZ.

Of the Danish stations, 7ZM and 7EC have been working occasionally with our men on 200 metres, but they are very weak. 7QF has gone down to 125 metres, and, of all the stations, European or American, who have moved to the short waves, he has certainly improved the most.

On 200 he was hardly ever heard, and when heard was very difficult to read. On 125 his signals are very strong indeed, sometimes uncomfortably so. It is curious that some stations do not seem to gain so much as others from the short waves. In contrast to 7QF, 2JF has reduced his wave-length, but the change does not seem to have done him any good. His signals are, of course, stronger, as are all signals on short waves, but the increase in strength is not very great in London.

A few Dutchmen are still working on 200

metres, but nearly all have adopted the short wave, there being about a dozen now working there. The only fresh success is, I believe, that of PCTT (Noordwijk) who "got across" the Atlantic some time ago. Their star station, of course, remains PCII (Leiden), who has worked a very large number of Americans.

Of the two Italians, 1MT does not seem to have been working much this month, and ACD was only working at the beginning of the month. The latter has now closed down for several weeks, while the whole station is rebuilt. The new transmitter at ACD will have accumulator high-tension supply, so that we shall at last have a Continental amateur using pure CW. May many more Continental (and British) stations follow his example.

XY (Geneva) is still working, and has worked several British stations, including 5DN and 2ZT. The latter, by the way, was not working for a long time until nearly the end of 1923, but in the short time since then, he has put up an imposing log of European work, including Danish 7EC, Swiss XY, and Italian 1MT.

Belgium now has an amateur transmitter, situated in Brussels, and using the call sign P2. His signals are quite strong, on about 118 metres. I have worked him several times, and believe he has also worked other British stations. Another station, P5, is working, but I do not know whether he is also Belgian.

A short time ago some of us were surprised to hear FL (Eiffel Tower) testing on about 110 metres. His signals were not extremely strong, and he sounded just like an amateur station, with a slightly unsteady wave. He worked with two British Stations (5KO, 5BV) at the beginning of his tests, but does not now listen for replies by radio.

Poldhu has also been testing on about 95 metres recently, his signals being of teriffic strength.

During January and February many of you probably heard a British station signing 2AP. This station had a really remarkable career, doing about as much "DX" in less than a month as most of our stations do in a season. The station started work on January 19, and closed down on February 11, during which time he worked nearly all the well-known British stations, and stations in France, Belgium, Holland, Germany, and Denmark.

The operator has now gone to North Africa, and hopes to put up a station there to work with England. If he succeeds he will be a very useful relay point between us and South African amateurs.

Last month I spoke about the possibilities of working Australia, and mentioned the wonderful low-power work which had been done by Mr. McClurkan (Aus. 2CM).

I have been deluged with letters asking whether the figures I gave were correct or misprinted, since 1,200 miles on ·004 watt seemed impossible. The figure for the power was correct, but the distance should have been given as 1,500 miles instead of 1,200! The plate voltage was 15, and the plate current ·25 milliamp (much less than most of us put into our wave-meters!) Even with this absurd power, signals at the other end (New Zealand 4AA) were still reported as QSA! After that, I think it is really up to us to "put it over" to Australia next year.

We hear very little of home DX, but nevertheless a large amount of excellent work is being done on very low power, Mr. Jacksonley, of Nottingham, for example, having got through to the London district on telephony with an extremely small input. The reception was carried out on a single valve by Mr. R. E. Broomfield, of Brixton Hill.

Next month the arrangement of "The Month's DX" will be somewhat altered, the local reports being written by several well-known local amateurs.

This should make these notes of interest to a wider circle of "hams" than is possible at present. General "DX" news will still be written as at present.

The Transatlantic "PA9."

By K. C. VAN RYN.

We give below some details of the Dutch Station PA9, which was specially licensed for the recent transatlantic tests.

BRITISH experimenters will have noticed the appearance of the Dutch short-wave station PA9 since the commencement of the transatlantic amateur tests.

As you are aware, transmission is not yet permitted in Holland. Nevertheless, steps have been taken by the writer since May, 1923, to obtain permission from the Government for a transmitter for the object of testing on very small wave-lengths. After much trouble, permission has been granted to use the licence of the Technical University of Delft (Holland) from October, 1923, to May, 1924. At the end of November last the writer, in co-operation with Mr. G. T. Eschauzier, planned to erect the station, both being students of the University.

The time for preparation was short, as the necessary components were not available until December 15. On December 17 we commenced assembling them, and on the 19th the first radiation took place. On December 22 at 1 G.M.T. (prompt) we started the automatic code relay, radiating 75 watts (2·5 amps.) on a wave-length of 195 metres.

At that time the set was comprised of nothing in particular. The "tickler coil" circuit was used fed at the filament side of the plate circuit. After a few days it rendered about 60 per cent. The plate current supply was 50 periods single rectified alternating current. The generator valve was a Phillips' 25, and the rectifiers (two in parallel) Phillips ZG5 tubes. On the fourth day of the tests a telegram was received stating that PA9 had been heard on the first three nights.

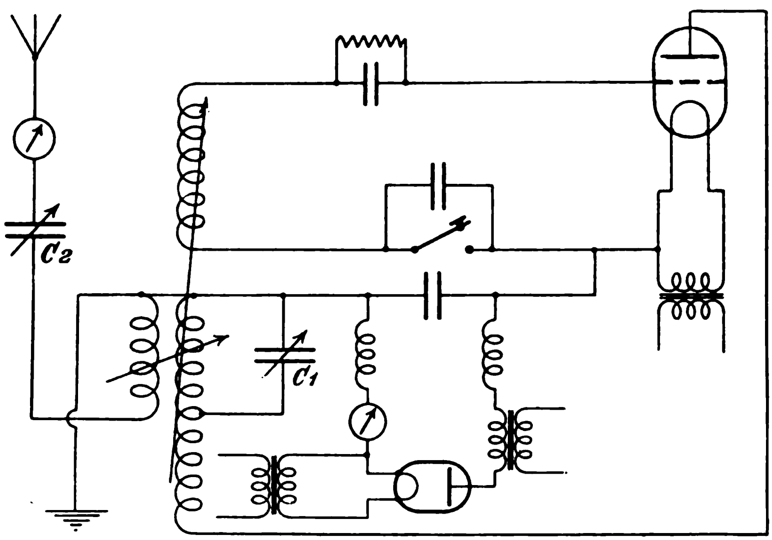


Fig. 1.—Showing the arrangement of the circuit employed, which, no doubt, is quite familiar.

Noticing the success in using very short wave-lengths, and the fact that many American amateurs were heard on them, we decided to turn to a shorter wave-length. Therefore, on December 31 we changed to 108 metres, using an entirely different circuit. Two days later we succeeded in communicat-

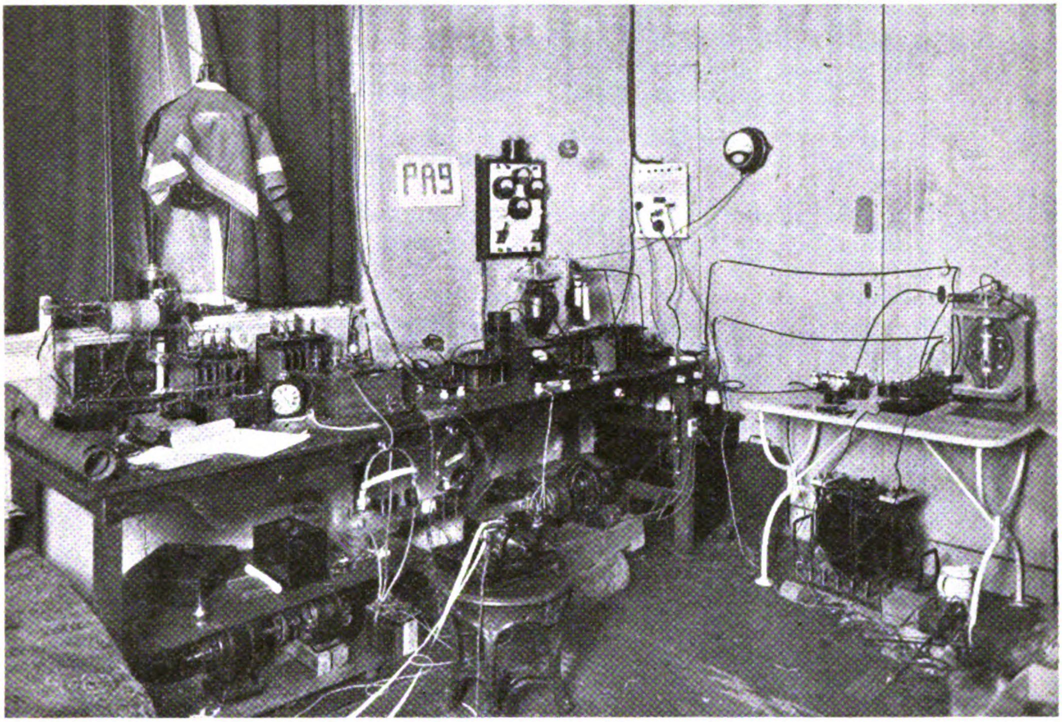


Fig. 2.—A general view of the apparatus which was rapidly arranged for the tests.

ing with U2AGC and U1XW, and since then we have maintained an almost daily communication, the total aerial energy being about 350 watts.

Primarily we started to tune the same circuit down to 100 watts, taking away each dead end which proved absolutely necessary, but the adjustments became too critical, and could not be relied upon. Changes were constantly taking place, the origin of which could not be overlooked. It should be remembered here that the Phillips valve works in the lower bend of its curve, so as to increase the efficiency, and this also made adjustment more difficult. We decided, therefore, to turn our attention to the circuit recommended in the October number of *Q.S.T.* by Messrs. Brown, Darne and Basim (3BNT), and found it much more flexible in operation. Here is the circuit changed in detail for the particular power supply. The condenser C is the only component that fixes the wave-length and the capacity should not be taken very small. In this particular case the capacity of C2 became rather small. The fundamental wave-length of the aerial being 207, it had a value of 60--70.

At the time of writing the first part of the transatlantic tests have been concluded, and we are looking forward to the communication tests. As already stated, we had the opportunity of working a number of stations of the first and second districts, and signals were always reported QSA (time mostly 0600-0820). Fading was scarcely noticed, and never as bad as on 200 metres. It will be interesting to note the results when a larger stretch of land is interposed.

It is intended to diminish the wave-length still more, and we expect to change to about 60 metres very soon.

Finally, I wish to state that we are quite prepared and willing to conduct serious tests in this direction, with any experimenters, especially those at long distances from Holland, and should be glad if they would communicate for this purpose with the writer at the address given.

Dutch PCII.

By a Dutch Correspondent.

PCII was one of the first Dutch stations to be received by British amateurs, and it is thought that some details of the latest improvements will be of interest.

In spite of our very, very bad situation owing to our position with the authorities we have tried to take our share in amateur transmitting, and soon we hope to make it still better.

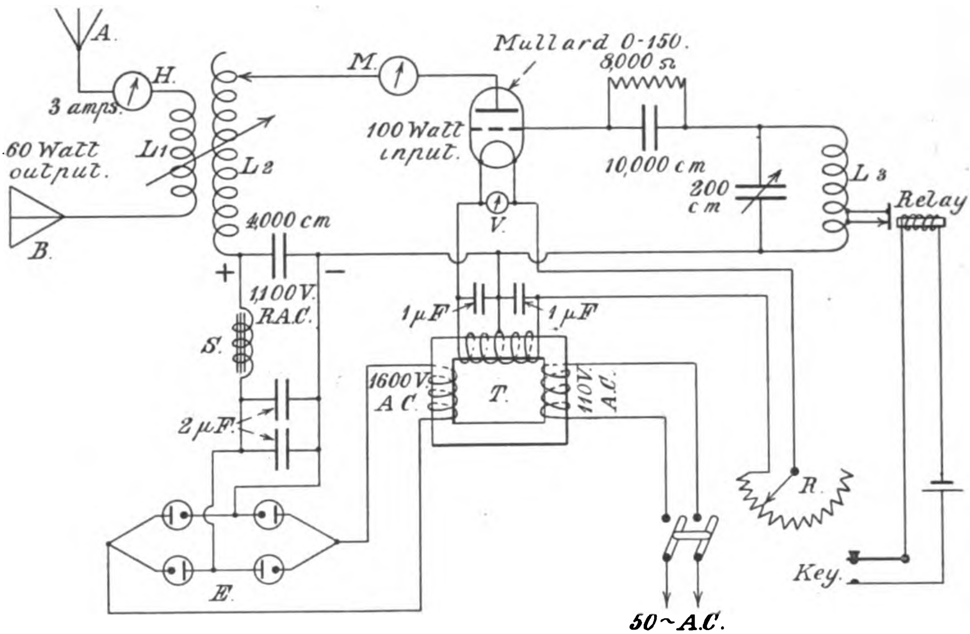


Fig. 1.—Showing the transmission circuit, which is described in detail in the text.

May I now introduce to you our famous PCII station?

It is located "somewhere in Holland," "ten miles from Amsterdam," "ten miles from the Hague," etc. He who has worked PCII knows better. Ask 2KF for details.

The other day I was looking for some news at his place and nearly stumbled down over a thin wire drawn one inch above the floor for about 24 feet, and then disappearing in the ceiling. It was part of the 390 square feet transmitting frame. PCII was just busy to put some 2 amps into it on a 220-meter wave. Later on the evening I heard him from my station (distance about ten miles) R9 on one valve (or A41 as we say now) with the frame at right angles to my direction.

Last week I went down to see why his signal strength had increased so awfully (!) Well, he showed me his hot-wire ammeter, rated 0-4 amps. It was burned out. That afternoon he had connected two additional wires to his counterpoise and the ammeter went up in smoke. And for some time he didn't know whether he had 5 amps. or 50 amps. in the aerial!

This is PCII—and now the apparatus.

The circuit in use is the Armstrong-Kühn transmitter with chemically rectified A.C. for plate supply. The most interesting point of this circuit is the position of the grid-coil, which is tuned by a variable condenser to the wave-length corresponding with the natural period of the antenna-counterpoise circuit. Whereas the plate-coil is not tuned critically

the slightest alteration of the grid circuit (for instance, shortening of a few turns of the grid-coil for keying) will stop the radiation absolutely. The grid-coil is placed at right angles to the antenna and plate-coil and about two feet apart to prevent coupling or reaction. The oscillations are set up only by the electrostatic coupling due to the internal elements of the valve.

The circuit is given in detail by Fig. 1. It explains itself fully, but for the experimenter it will be interesting to have the constructional data as completely as possible.

The components of Fig. 1 are as follows:

L_1 Aerial inductance, 9 turns diameter 12 cm., revolving inside L_2.

L_2 Plate inductance, 19 turns, diameter 17 cm., tapped.

L_3 Grid inductance, 23 turns, diameter $9\frac{1}{2}$ cm.

R Filament resistance, shortened when filament is properly lighted; used only for starting the valve slowly to prevent the building up of undesired high-tension currents.

E Chemical rectifier, consisting of four groups of eight jam-pots connected to get full-wave rectification. The electrodes are Al and Pb. The solution is 5 to 7 per cent. phosphate of ammonium with distilled water.

T Transformer with primary winding for the 50-cycle 110-volt line, a step-down coil with midtap, wound to the proper filament voltage, and a high tension section giving 1,600 volts. After passing the rectifier and the filter circuit, the R.A.C. voltage left is 1,100 volts. The cross section of the transformer-core is $4 \times 5\frac{1}{2}$ c.m.

S Filter-choke of 3,000 turns 0·5 mm. wire on core of $3 \times 3\frac{1}{2} \times 15$ cm.

V Voltmeter controlling filament voltage.

M Ammeter giving the milliamps. in the plate current.

H Aerial hot-wire ammeter. Shows 3

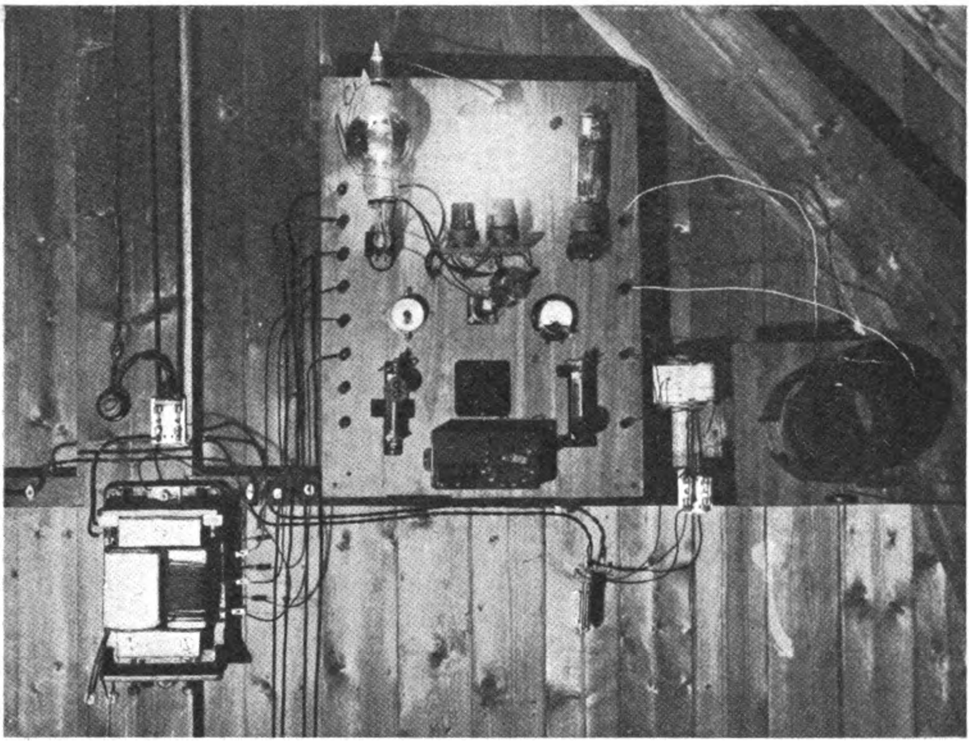


Fig. 2.—A near view of the valve panel and transformer.

amps. on 100 watts input and 60 watts output.

The transmitter apparatus are at 20 ft. distance from the receiving set. The keying is done by a relay-line, as shown in the drawing.

trapezium. The operating wave-length with L_1 as aerial coil is 203 m.

To make the operations for switching-over as simple as possible, as well as to eliminate all losses developed by complicated wiring, PCII has erected a separate receiving aerial

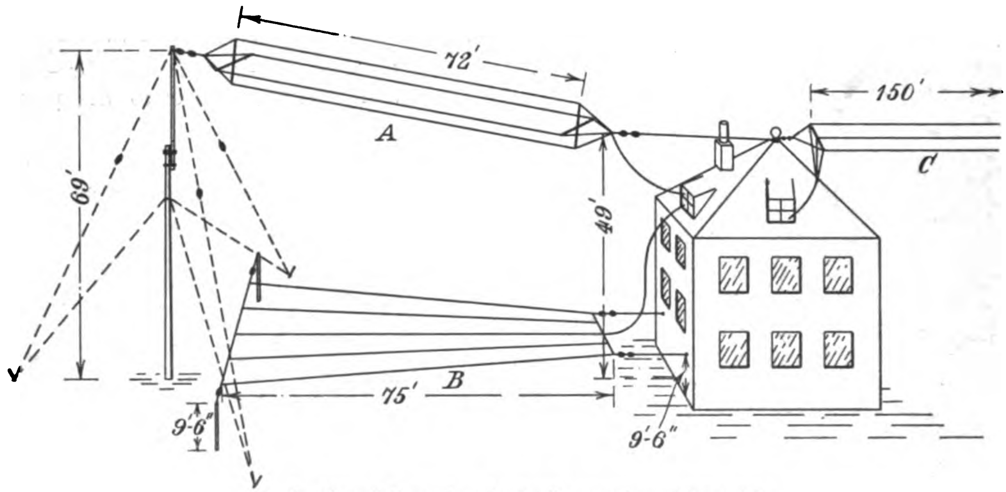


Fig. 3.—The radiating system showing the separate receiving aerial.

The part of a transmitting station outside of the apparatus is in no way less important. Probably PCII owes very much of his fine results to the well-constructed antenna system.

(C) of the inverted L type, 150 ft. in length, three wires. This aerial runs at right angles to the transmitting antenna system, and at proper distance to eliminate losses, etc.

Fig. 2 gives a photograph of the transmitter

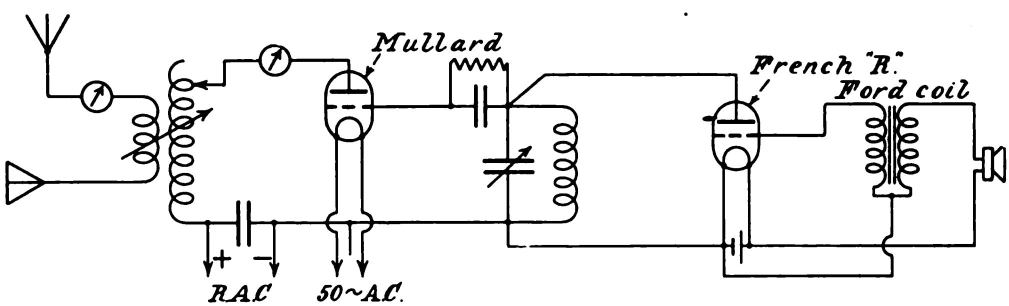


Fig. 4.—For telephony, absorption modulation and a tuned grid circuit are employed.

The four-wire cage aerial (A) is supported by the roof of the house, and a splendid 69 ft. pole, average height 60 ft. above the ground, and 50 ft. above the counterpoise. The counterpoise (B) is suspended symmetrically under the aerial, consisting of five wires of 75 ft. each. The form is of the fan type, or better still, it can be compared with a

valve panel, the inductance coils, and the transformer. Note the simple wiring. Besides the 0-150 Mullard at the left upper corner of the panel, there are mounted three Telefunken 5-20 transmitting valves, two of which are connected in parallel with the "big bottle" to increase the power. The third 5-20 valve (type RS.5) is used for rectifying

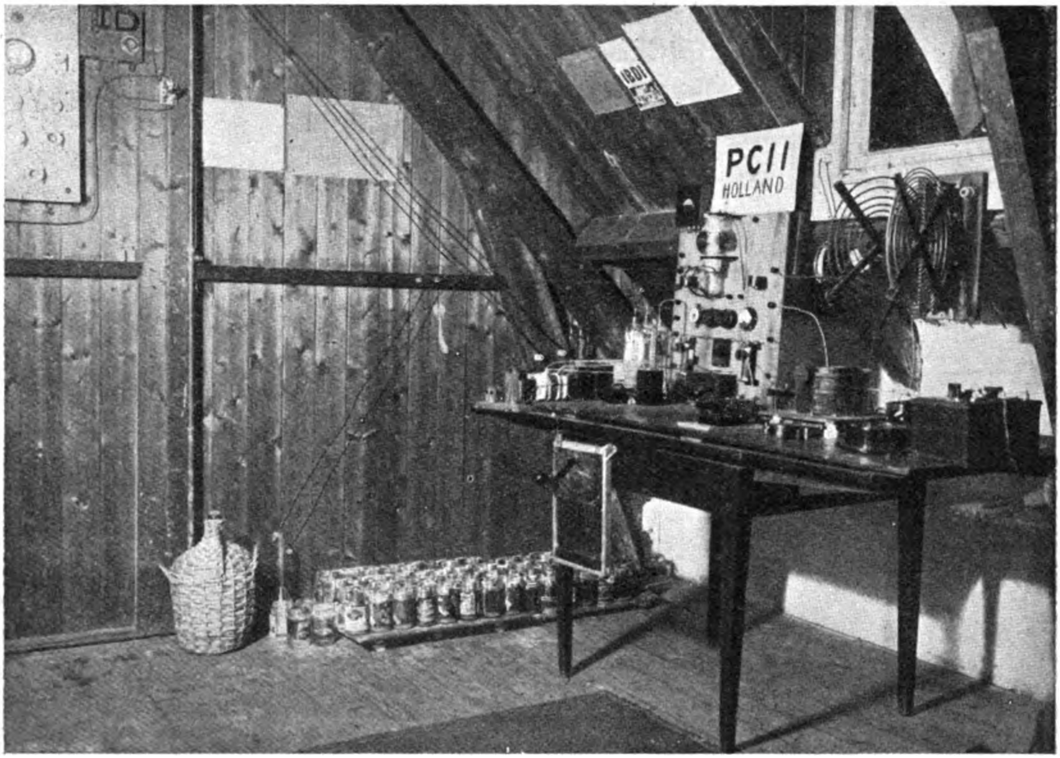


Fig. 5.—A General View of the Apparatus. Note the Chemical Rectifier in the Corner of the Room.

purposes. Right in the centre of the panel is a French R valve (receiving type) used as modulator for telephony.

Fig. 4 shows the general arrangement of the telephony circuit (got it from 2KF !). Good results were obtained at the first tests with 5KO (Bristol), reporting strong and clear speech.

The receiver in use for the short waves is a special Reinartz one-valve set of original design, using normal spider-web plug-in coils. Waves down to 40 m. can be received with this arrangement without difficulty. American amateur signs are coming in very well with one valve.

Overseas Transmission.

Amateurs holding transmitting licences are reminded that communication with foreign countries must not be conducted without permission from the Post Office. When working tests, the following international prefix should be used:

V A	Canada	K B	Germany
O U	Denmark	I	Italy
O N	Belguim	F	France
P A	Holland	E A	Spain

Experimental Station 7ZM.

BY GUNNAR BRAMSLEV.

Most British experimenters are familiar with many of the Continental amateur stations, but it is thought that little is known of Danish methods. Below will be found details of 7ZM, which was one of the pioneer stations.

UNTIL quite recently nothing was heard from Danish amateurs, and although radio experimenters exist in Denmark, as in every country, they are very few, and not many of them possess transmitting apparatus. The Government restriction upon amateur transmitting (half a year ago, also receiving) has not yet been removed, and this is the probable cause of so few experimenters.

A description of 7ZM will possibly be of interest, as this station was the first that was heard in England. The writer started wireless experimenting in 1920, when the station was equipped for crystal reception only. Since then the receiver has undergone many alterations, and the first valve transmitter was started in May, 1923.

The antenna system is of the inverted L type, and consists of three wires 135 ft. long supported on 3-ft. spreaders, 3-wire lead-in about 20 ft. long. The mast at the lead-in end being 33 ft. high. The distant end is supported to the chimneys of a house. Unfortunately a nine-wire counterpoise cannot be installed, but a one and two-wire which is used for transmission has given very satisfactory results, having reduced the aerial resistance considerably. The surroundings are far from ideal for transmission, as the house is situated at the foot of a hill

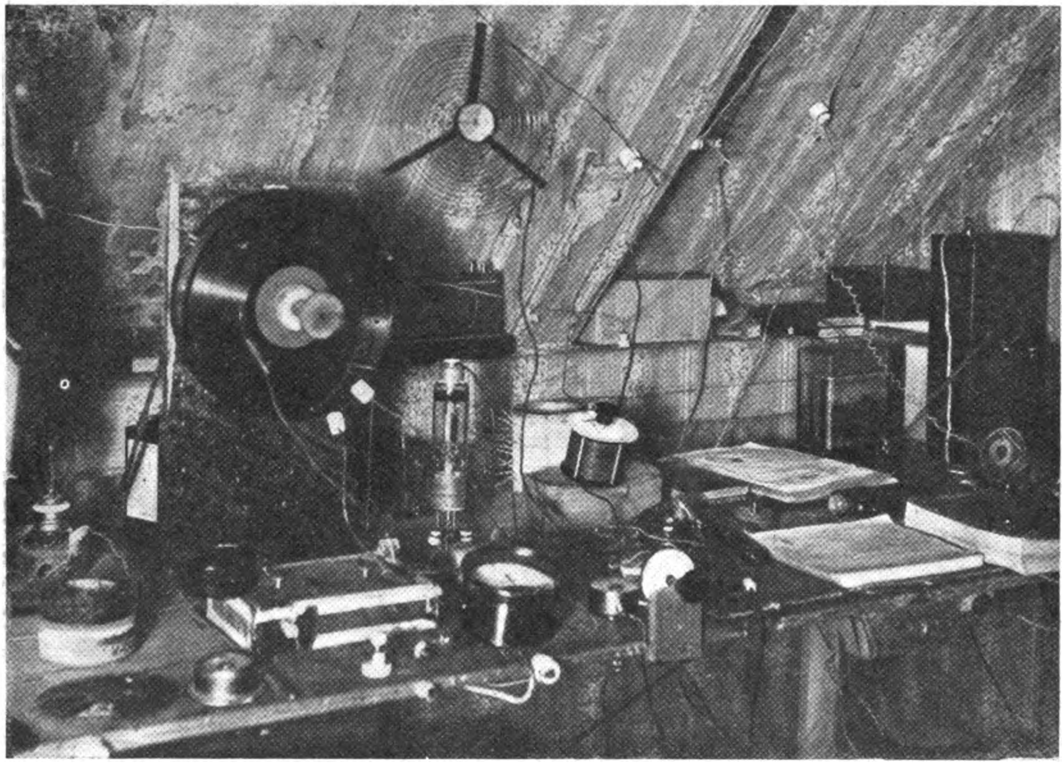


Fig. 1.—A near view of the transmitter.

and almost completely screened by trees and other houses. The aerial seems rather long for 200-metre transmissions, but difficulty only arises when trying to get under 180 metres.

A diagram of the transmitter is seen in Fig. 2, and a photo in Fig. 1. The valve is a Telefunken type RS.5.C.II.a with filament consumption 10-12 volts and 3 amperes. At present it is only supplied with 10 volts. The tuning inductance consists of 18 turns of 1.5 mm. bare copper wire tapped at each turn. Both this and the grid coil, which is aperiodic, can be seen in the photo wound on old gramophone records. The relay, which is controlled by the key on the receiving table, is placed in the plate circuit. It has been very difficult to obtain a good high tension supply, and I now use 220 volts D.C. from the mains in series with a home-made accumulator battery with about 80 small cells. This gives 380-400 volts, but a higher value was desirable. The set is not used much for telephony transmissions, but ordinary grid modulation is employed, giving very good speech at distances up to 20 miles with an aerial current of 0.2.

With this transmitter a radiation of 0.75 amps. is obtained when the input is 10 watts, but I hope to increase this in the near future with a better H.T. supply.

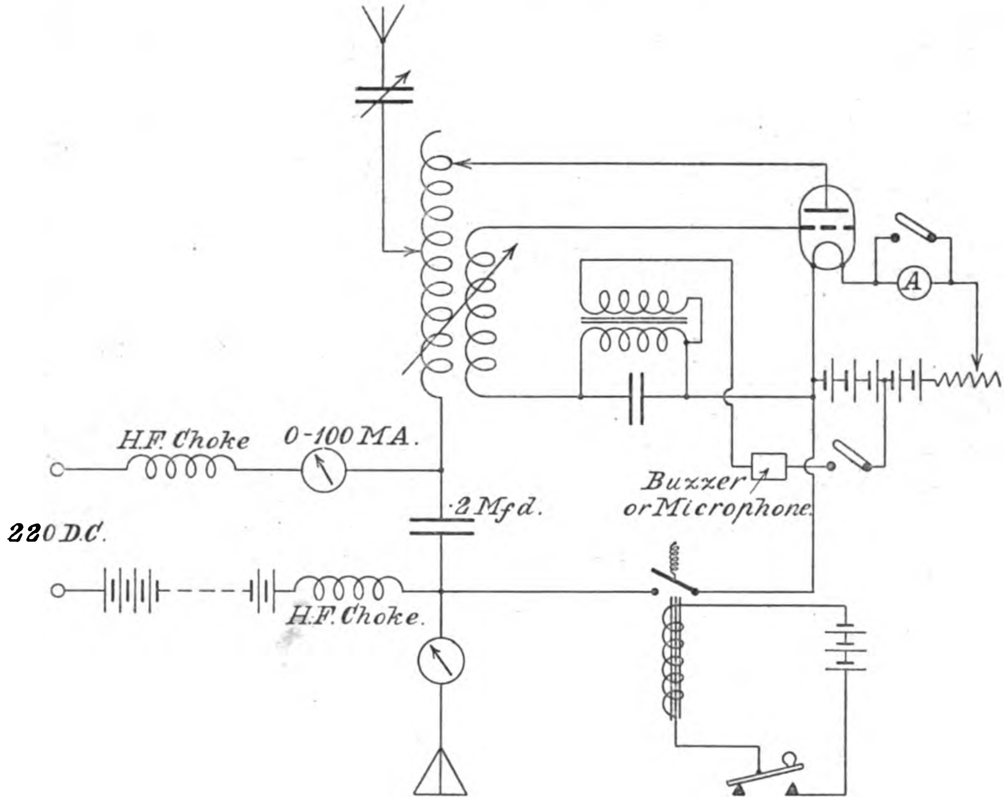


Fig. 2.—The transmission circuit showing method of keying.

The receiver portion of 7ZM will be seen in Fig. 3. On waves above 300 metres home-made honeycomb coils are used for tuning, and on the short waves 120-300 metres special single-layer, large diameter cylindrical coils are used. Two valves are used, the amplifying valve either being H.F. or L.F. If large amplification is required all the four valves can be put together as one H.F. (tuned anode), detector, and two L.F. The various parts, including two home-made inter-valve transformers and four filament rheostats, can easily be identified in the photo.

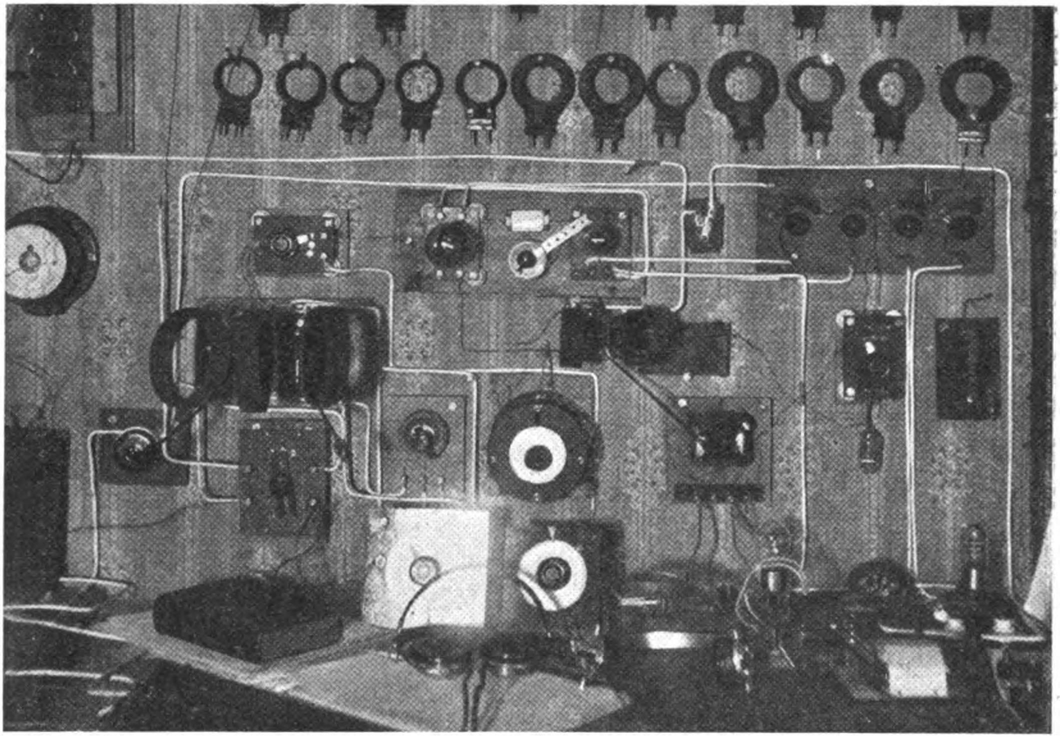


Fig. 3.—A general view of the receiver.

With this receiver all the British broadcasting stations can be heard at any time when it is dark, and it may possibly interest English amateurs to know that nearly all Danish broadcast listeners get their entertainment from the splendid programmes of the B.B.C. stations; their own broadcasting station, Lyngby, being far from perfect. English amateurs come in very well over here on two valves in spite of the distance being in the neighbourhood of 600 miles. Over 140 foreign experimental stations have been logged, including four American. Sometimes the distance between England and Denmark is covered with very low aerial currents and small power. For instance, in August last year I heard 5RZ, when he was using 3 watts input and 0.12 in the antenna, and a few days ago 2IJ, who stated that he was radiating 0.15.

The first long distance transmission from 7ZM was done on September 8, 1923, when my "test" call was answered by 2KW; owing to QRM, however, communication could not be established. The next Saturday greater success was obtained, and the first two-way communication established with 2JF who reported the signs QRK on one valve. Since then I have communicated with 2DF, 5KO, 2NA, and many others The longest transmitting range has been 1,400 kilometres to 8CT.

In conclusion, I may say that the station is situated in Roskilde, about 20 miles west of Copenhagen, and I shall always be pleased to arrange transmission or receiving tests with British amateurs.

The Trend of Invention.

We summarise below the more important wireless inventions which have been disclosed during the month, special reference being made to those of immediate interest to the experimenter.

Improved Super-Regenerative Circuit.

Various modifications of the Armstrong super-regenerative circuit, of which the Flewelling circuit is the best known, have been devised, in which the quenching frequency is supplied by grid-leak howl. The resistance of the leak in an autodyne regenerative receiver is made of such a value that the accumulation of negative potential on the grid of the valve periodically stops the valve oscillating, the frequency of this intermittent stopping and starting being controlled by the use of a variable grid-leak. British Patent Specification No. 192,090 (Westinghouse Co. and J. Slepian) points out a defect which ordinarily attends the working of such circuits, and describes an arrangement intended to overcome the defect. The trouble lies in the fact that the negative D.C. potential that accumulates on the grid of a valve using the usual condenser and leak can never exceed, or even reach, the peak value of the impressed signal voltage, and the quenching cannot take place until the oscillations have built up to a value determined by the limits of the valve's characteristic. The chief object of the invention is to cause the incoming signals to put a greater negative D.C. potential on the grid than the peak values of the alternating grid potentials themselves. Fig. 1 shows one way of attaining this end. The grid condenser and variable leak are placed at L and M, instead of the usual position immediately next to the grid. The plate circuit C, D is coupled not only to the grid coil F, but to an auxiliary coil E, which is in series with a two-electrode valve J, as shown. It is stated that the arrangement allows the quenching due to the negative blocking potential to take place before the oscillations have built up to a maximum. The necessary blocking potential is smaller for weak signals than for strong ones, so that a more or less proportional amplification is obtained. Instead of using a two-electrode valve, a two-grid valve may be used instead of H, the connection which otherwise would have gone to the plate of the two-electrode valve going to the extra grid.

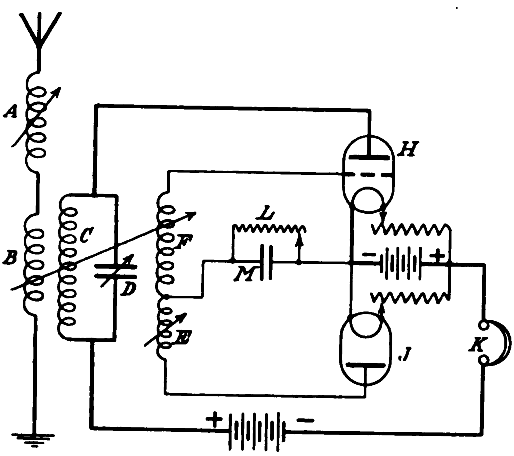


Fig. 1—A super-regenerative circuit.

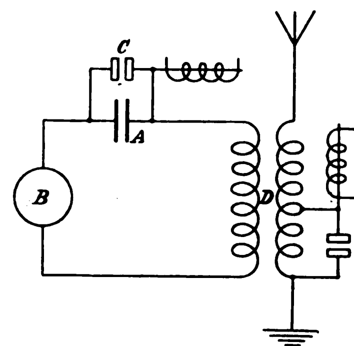


Fig. 2.—A keying system delivering greater power to the dots

Morse Keying.

One of the difficulties experienced in keying long-wave high-power transmitters using aerials with low-damping is that the full amplitude of oscillation in the aerial is not established immediately, but may take an appreciable fraction of a second to grow. Thus, with fairly high speed sending the dots may be lost or become indistinct. One solution of this difficulty that has been sug-

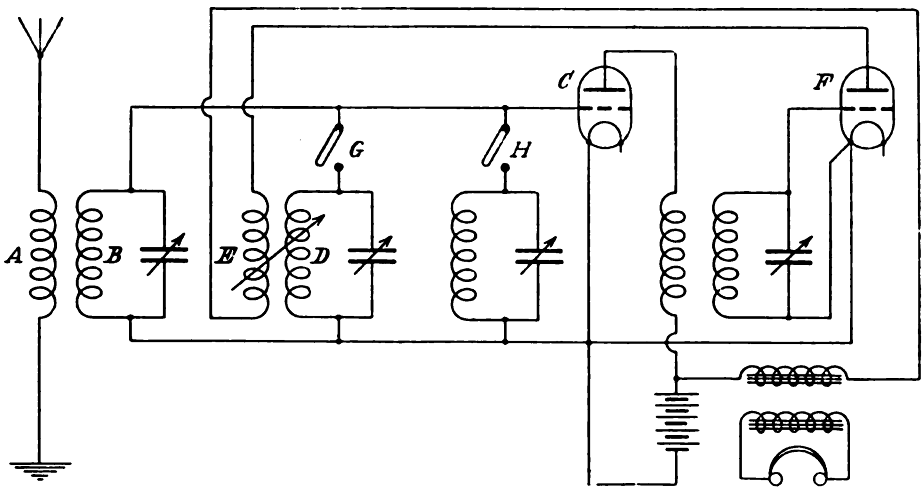


Fig. 3.—The fundamental principle of the Hinton rejector system.

gested is to use more power on the dots than on the dashes.

Fig. 2 illustrates a scheme for delivering greater average power into an aerial during the dots than the dashes (Société Française Radio-Electric).

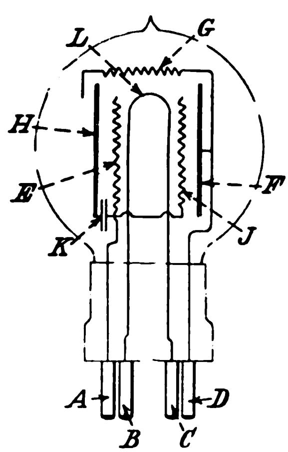


Fig. 4.—A "resistance capacity coupled" valve.

C and E are contacts capable of being simultaneously opened and closed. When the contacts are open a certain power will be delivered from the generator B to the aerial through the H.F. transformer D. When the contacts are closed the condenser A in the closed circuit is short-circuited, and a few turns of the aerial inductance are short-circuited, and by correctly adjusting the number of turns shorted the whole system may be maintained in resonance, but delivering greater power to the aerial. If, then, it is arranged that the contacts C and E are closed during dots and open during dashes, a greater average power is transmitted during the dots. The specification describes other means for producing the same effect by iron-cored windings supplied with independent saturation-control fields.

The Hinton Rejector.

The use of parallel-tuned rejector circuits to by-pass or cut out all but unwanted signals is as old as wireless itself. In order that such a circuit shall be very sharply selective, however, it is necessary to use a large capacity and small inductance, and the H.F. resistance of the circuit should be as nearly as possible zero. Unfortunately, such a circuit is not easy to construct, but the necessary effect can be obtained in some degree by using a rejector circuit whose damping at the resonant frequency is neutralised by the use of regenerative reaction coupling from a three-electrode valve. This is the principle underlying the Hinton rejector (British Patent 209,455, N. P. Hinton), an elementary form of which is illustrated in Fig. 3. A, B, C, and F are components of a normal type of two-valve receiver employing one stage of transformer-coupled H.F. amplification. D is an additional tuned circuit which can be connected in shunt with B by closing the switch G. By means of the coil E reaction

coupling is established between D and the plate circuit of the last valve F, this coupling being arranged to bring the circuit D nearly to the point of oscillation. Under these conditions circuit D rejects sharply at the frequency to which it is tuned. It should be noted that there is no magnetic coupling between D and B. A second rejector circuit may be brought into play by closing the switch H.

The specification referred to describes various modifications in which the principle is applied to audio-frequency tuning as well as radio frequencies. It is not quite clear, however, where the fundamental difference lies between the Hinton rejector and the ordinary regenerative receiver where the resonance is sharpened up by the use of reaction on one or more tuned circuits. Surely would not the circuit in Fig. 3 work just as well if we removed circuit B, and tuned in straight away on D ? In this case we should have a circuit commonly used ever since the invention of the hard valve.

A Novel Idea in Amplifying Valves.

The valve illustrated in Fig. 4 really consists of two resistance-capacity coupled valves, complete with coupling resistance and condenser in one bulb. Only four pins are necessary. It would be interesting to know how such a valve functions as an H.F. amplifier. (British Patent 209,775, E. K. Hunter).

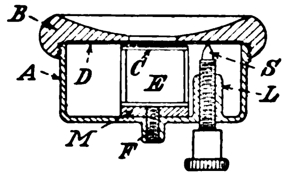


Fig. 5.—Showing how the telephone is adjusted.

Telephone Receivers.

Fig. 5 shows a method of adjusting the clearance between the diaphragm and pole-pieces of a telephone receiver. The diaphragm seating and pole-pieces are so ground that the diaphragm normally lies flush against the pole-pieces. The thumbscrew is tipped with ivory or some similar elastic material and it is turned until it just urges the diaphragm from the pole-pieces. It is claimed that this gives a nice adjustment of clearance and improves the quality of reproduced speech. In spite of its extreme simplicity the idea strikes us as a particularly useful one. (British Patent 201,212, A. C. Brown.)

Correspondence.

Letters of interest to experimenters are always welcome. In publishing such communications the Editors do not necessarily endorse any technical or general statements which they may contain.

To the Editor of EXPERIMENTAL WIRELESS.

DEAR SIR,—The article on "Transatlantic Telephony" in the current issue of EXPERIMENTAL WIRELESS is one which is very valuable to the experimenter, and personally I appreciate the large amount of practical detail supplied. There are, however, one or two points of theory on which I venture to disagree.

The author says that 1 ampere aerial current 80 per cent. modulated is better than 2 amperes 35 per cent. modulated. It can be shown that the useful effect in the receiver is proportional to the product of the aerial current and the modulated amplitude. The relative effects produced in these two cases, therefore, are 0·8 and 1·4 respectively, *i.e.*, the former is little more than half as good as the latter, and, further, in a less carefully designed transmitter than the one described would be considerably more liable to distortion.

With reference to item five on the list of transmitter requirements, the following sentence occurs: "Sharpness of tuning of the modulated output is a matter of efficient transmission, *i.e.*, utmost concentration of the available energy into a definite operating waveband of least possible width . . . and lies in the correct design of the antenna system . . . ." etc. As the band of frequencies, and consequently wavelengths, constituting a modulated carrier wave is equal to exactly double the modulation frequency, and hence is determined solely by the pitch of the highest note which occurs in speech or music, I have difficulty in seeing what effect the antenna system has.

It is stated that the aerial ammeter is inductively coupled because of the resistance introduced by connecting it direct. The same amount of power is absorbed by the meter in giving a reading however it is connected, but in the inductive method the loss is not less, but greater, due to the added loss in the coupling coils, and, further, the meter must be recalibrated, the readings being now uncertain and varying with the coupling.

A choke, L7, is shown in order to prevent H.F. currents taking a path along the L.T.— lead, but no choke is shown in the L.T. + H.T.— lead, so that any H.F. currents stopped along the former will have no difficulty in making their way to earth *via* the latter.

In Fig. 3 a variable resistance is shown in shunt with the H.T. output. If a resistance is required here at all it would surely be in series, as usually a voltmeter takes enough current from such a supply without wishing to increase it by a shunt.

In describing the speech choke, the inductance is given as 12 microhenries. This is obviously meant to be henries.

—Yours faithfully,

MARCUS G. SCROGGIE.

To the Editor of EXPERIMENTAL WIRELESS.

DEAR SIR,—In this month's issue, in an article entitled "Transatlantic Radio Telephony," the writer states that on January 20 last, "two-way transatlantic telephony" was successfully established for the first time in history.

A keen "DX" experimenter myself, and particularly in the direction of transatlantic working, I should be glad if the author of the article in question will be good enough to make known through your journal the following points :—

1. The station in America with which the British Station worked "two-way telephony," giving address and call signs of both stations.

2. The type of receivers used at the respective stations.

3. The wave-lengths used, and the powers employed by the U.S.A. station.

The reason I am anxious to ascertain the above details is that I am in constant communication with the headquarters of the A.R.R.L., who are not at present aware of this achievement, and would welcome any particulars relating to such a performance, as would, no doubt, many of your readers.

—Yours faithfully,

J. A. PARTRIDGE (G.2KF).

The Efficiency of the Propagation of Short Waves.

To the Editor of EXPERIMENTAL WIRELESS.

DEAR SIR,—It appears to be a matter of wonderment that some workers on short waves are able to cover with apparent ease distances, to cover which high-powered stations, with all their attendant complicated apparatus are employed using very long wave-lengths.

In trying to obtain a clear understanding of any complicated subject it is of great assistance to find, if possible, an analogy in some common object which will, by its familiarity, appeal with ease to the mental faculties, and in comparing the propagation of short and long waves the following analogy may materially help one to appreciate the action of a radio wave, and it might be imagined thereby that long-distance communication on short waves is not so dependent on power, but more on such factors as time and condition.

If we wish to drive a screw into a piece of wood there are certain factors to be taken into account which decide the necessary force to be employed to do the work. It is obvious that a screw having a very fine pitch—that is, where the threads are very close together—will require for a given diameter less power to drive it than one with a coarse thread —that is, where the threads are far apart. The "pitch" of a screw thread is the distance in a straight line parallel with the axis of the screw from the top of one thread to the top of the next thread. This corresponds to what is known as the wave-length of a radio wave, and it is measured in like manner. Given the same power applied in each case, the fine-pitched screw will be driven the required distance in less time than the coarse-pitched screw. We have, therefore, time factor being constant, a variation in power; and, conversely, power factor being constant, a variation in time or rate of progression. But the power factor is partly proportionate to the pitch, so that time factor will also vary in like proportion and time becomes dependant on power.

Now apply this to radio waves. Let the pitch of the thread represent the wave-length and the depth of the thread the amplitude. The long wave has similar charactistics to the coarse-pitched screw—it takes more power to drive it than the short wave or fine-pitched screw, and its rate of progression is also less. If it were possible to measure with accuracy it might be found that the time occupied in transit through a given distance is greater for a long wave than a short one. But the speed of travel of radio waves is so great that variation in speeds need not be taken into consideration for purposes of communication. It would appear that impedance is an important factor, as in the case of a fine screw thread driven through a dense substance, where the resistance might be so great as to altogether deflect its direction or to so damage its delicate thread as to make it no longer a screw. It seems under good conditions —that is, where the intervening medium is a proper one—the transit of communications over great distances by short waves may actually be an advantage when one considers the very much greater distance in space covered by the passage of a long wave of great amplitude, the risk of atmospheric disturbances being thereby increased, but one must also assume that under bad conditions, where the impedance is considerable, and particularly where it is irregular, the delicate short waves may be so deflected or broken up as to become a negligible quantity.—I am, dear sir, yours faithfully,

"SHORT-WAVE."

To the Editor of EXPERIMENTAL WIRELESS.

DEAR SIR,—In your March issue of EXPERIMENTAL WIRELESS the author of the article on "High-Frequency Resistance" has made one very serious mis-statement, which may lead other experimenters into difficulties. In the latter part

of his article he mentions a method of measurement using a "Moullin" voltmeter (anode rectifier type), and he states that the voltmeter *can be calibrated on D.C.*

This is emphatically *not* the case, as the accompanying curves show, which were taken on my own instrument. As a matter of fact, this should be obvious on theoretical grounds, since the action of the voltmeter depends on the rectifying properties of a triode (*i.e.*, on the *rate of change* of slope of the characteristic curve of the triode), whereas if D.C. is applied between the grid and filament no rectification occurs and the anode current depends directly on the slope of the characteristic curve, which is different for different values of applied D.C.

I should be glad if you will draw the author's attention to this, as the errors involved are large (at 2 volts over 70 per cent. in the case of my own instrument).

The "Moullin" voltmeter is such a useful and convenient instrument that it would be a pity if experimenters were put off using it owing to incorrect instructions for its calibration.

Full instructions for calibrating are given in Mr. Moullin's paper before the I.E.E.—it is done on low-frequency A.C., *not* D.C.

I have used methods 2, 3 and 4 for measurement of H.F. resistance, with a "Moullin" voltmeter across the coil in place of a current-measuring device, such as a hot-wire ammeter or thermo-junction.—Yours faithfully,

DESMOND DE BURGH,
F/L., R.A.F.

To the Editor of EXPERIMENTAL WIRELESS.

DEAR SIR,—I would like to suggest to the manufacturers of wireless apparatus that they might give a more scientific description of their apparatus than they do at present. I refer, in particular, to audio-frequency transformers. I see no reason why the impedance at a given frequency should not be published along with the ratio of transformation, instead of the present type of description, which is obviously the result of a more than fertile imagination.

In the case of the telephone receiver, it appears to be usual to give only the D.C. resistance, which is nothing more than a confession of ignorance of the conditions under which it operates.

There are no objections to the imaginative type of description, apart from the fact that it is valueless to experimenters, so why not give physical data at the same time and thus satisfy both the experimenter and broadcast listener.—Yours faithfully,

"5BG."

To the Editor of EXPERIMENTAL WIRELESS.

DEAR SIR,—I should like to call your attention to a much-needed protection for wireless experimenters, owners of broadcast receivers, and all users of radio valves in the shape of some guarantee that the valves they buy have not been previously used on demonstration sets.

Under present conditions there is nothing whatever to prevent the unscrupulous use of a valve for any period, it being subsequently put back into stock and sold as new. The purchaser is shown that the filament is unbroken by the simple process of heating it to incandescence, and this is all the guarantee he gets. The fact that a considerable part of the life of the filament may be spent by reason of such unscrupulous use is entirely overlooked.

I would suggest that the desired protection be afforded by the manufacturers placing a seal, in the form of an adhesive strip, across the grid and anode legs of a valve. This would effectively prevent

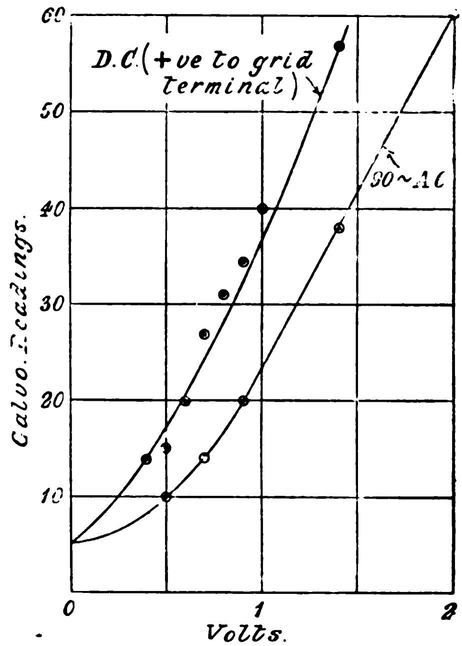


Fig. 1.—Calibration of Moullin voltmeter.

its use in a holder, and at the same time would not hamper the very necessary operation of testing the continuity of the filament.

Copies of this letter are being sent to the Radio Society of Great Britain, the principal technical magazines, and the various valve manufacturing companies.—Yours faithfully,

J. W. HADFIELD CRAVEN.

To the Editor of EXPERIMENTAL WIRELESS.

DEAR SIR,—I thought that perhaps a short account of some receiving experiments carried out in a train might be of some interest.

A three-valve set (1-v-1) was used and a 14-foot aerial. 10 feet of wire being stretched in the corridor and the remaining 4 feet serving as a lead in. An earth was obtained on the steam heating pipes.

The experiments were carried out whilst travelling between Ipswich and London, between the hours of 12 and 3 p.m. Signals were first received in Ipswich station, the musical programme from Radiola being clearly audible. On entering the tunnel on the London side of Ipswich station all signals vanished although the receiver had a wavelength range of from 300 to 5,000 metres.

On leaving the tunnel Radiola was heard again and signals from Ongar were received with strength about R7; GFA was received with about the same strength.

Spark stations on 1,000 metres were received and telephony from Croydon aerodrome, also various C.W. stations.

Observations were then made of the variations in strength of the signals from Ongar.

It was noticed that when passing under a brick arch fading occurred. The fading started a few feet before the arch was reached and continued for a few feet on the other side of the arch, the signals being a minimum under the centre of the arch.

A signal-box on the N. side of the line caused considerable fading, but the most noticeable decrease in signal strength occurred when passing under a metal signal gantry, the C.W. practically vanishing when directly under a gantry and fading being noticed at least 10 feet on either side of the structure. A curious point noticed was that the large Bryant and May's building just north and close to the line caused no appreciable fading.

It was thought possible that some fading would be caused by the various structures slightly altering the aerial tuning and so cause variations in signal strength. This, however, was not found to be the case, the C.W. beat note remaining quite constant.

More fading, and perhaps variations in the beat note, would probably have been noticed had a station with a shorter wave-length been observed, but no continuous short wave signals were available.

Hoping that this account may prove of interest to some of your readers.—Yours faithfully,

R. E. GRAY.

Points from Letters.

Mr. A. L. Williams, of Kensington, writes to us as follows: "On the morning of February 20 I was testing a tuner I had just completed for short waves and observed the following interesting phenomena. I was receiving KDKA as a dist nt station of known wave-length with 'untuned' aerial. Leaving the set on, I disconnected the aerial to try the effect of another turn in aerial coil, and found that KDKA still came in at almost same strength. I then disconnected earth lead and managed to receive this station clearly on the loud speaker (having burned out my phones) on detector and 2 L.F. on a coil 4" diam.!

"On looking further into this, I found that I was not truly working without an aerial, because when the end of the aerial (which hung down six feet away) was 'earthed,' nothing but a faint 'carrier' could be heard. This effect is only noticeable below 120 metres.

"Touching aerial terminal of tuner, aerial wire, or altering distance of aerial wire from tuner seemed to have no effect, though it is not possible to remove the wire more than six feet, due to size of room.

"Reception that morning was good, four other American broadcasting stations being clearly audible on loud speaker."

No doubt other readers have experienced similar effects. It would be impossible to say exactly how the receiver was energised without full details of the apparatus and aerial system. What actually happens, of course, is that the received energy is passed on from the aerial to the set, probably by a combined inductive and capacitative effect. It is well to remember that at frequencies of the order of 3,000 kilocycles, conditions are very different from those obtaining on wave-lengths normally used for commercial work, particularly where capacities are concerned.

Wireless Spoil Sports.

[We particularly draw the attention of our readers to the following letters relating to interference with broadcasting. They serve to indicate once more the feeling which is prevalent amongst many broadcast listeners.]

To the Editor of the "Southern Daily Echo."

SIR,—Hundreds of listeners-in of wireless programmes in Southampton and district must have been annoyed beyond endurance last night by a would-be transmitter of Morse code, who kept up a terrible din by repeating the same two letters with a "buzzer" for at least an hour. The noise was so intense in this district that on a three-valve set working a loud speaker it could be heard distinctly several rooms away, and came in at about the same volume as the Savoy bands on the Bournemouth wave-length. This must be either the work of an amateur at close quarters, or, if broadcast all over the town, must be from a very powerful set. If the owner is so ignorant of the rudiments of wireless that he is unaware of spoiling other people's reception for miles around, then he is obviously unfit to hold a transmitting licence, if he has one. Cat-calls owing to oscillation have been very common of late, and have been generally regarded as the result of carelessness, but this last effort seems to prove the existence of the kind of "fiend" who delights in spoiling other people's pleasures out of pure mischief. If those who were affected last night will kindly drop me a P.C. stating the intensity with which they received the signals as compared with the Bournemouth Station's output, it will be possible at least to localise the offender, and, having done this, will allow the

B.B.C. to deal with him as they think fit.—Yours faithfully,

(Signed) D. S. BAKER.

"West Brook," Millbrook Road.

February 6, 1924.

DEAR SIR,—I note your correspondent, Mr. Baker, has been disturbed by some powerful station sending the same two letters with a "buzzer" for at least an hour, and that he wishes to locate the offender with a view to his being reported to the B.B.C. Well, Sir, the "buzzer" is a high-power transmitter of probably 125 kw. (some "buzzer"), and the offender an Admiralty Station. In some cases other such stations create the same so-called terrible din. They did so before broadcasting became a hobby. Probably this will save many P.C.'s.—Yours faithfully,

(Signed) ALBERT PARSONS.

65, Cromwell Road, Winchester.

February 7, 1924.

SIR,—*Re* the letter in last night's *Echo*, may I be allowed to enlighten the author on a few points ?

1. The "buzzer" was C.W. from a powerful station.
2. The two letters were P.1.
3. The Morse did not emanate from a local amateur transmitter, as they are forbidden to send during broadcasting hours.
4. The signals were received with great volume all over the town.
5. The same station was working yesterday evening (Wednesday), sending P.1, changing to P.2, and then a jumble of letters and figures, finishing with A.R. (end of message). No call sign given.
6. The signals were heard on every wave-length of the B.B.C.
7. When B.B.C. closed down signals ceased, and could only be received by making receiving set oscillate.

Trusting this will clear the air somewhat for Mr. Baker's inquiries.—Yours faithfully,

"6JW."

SIR,—Will you permit me to thank the numerous users of wireless who sent me their experiences yesterday. Dozens of letters arrived from all parts of the town and suburbs—Totton, Hamble, Westend, etc.—all giving practically the same account, that they had to close down on Tuesday night after 10 o'clock, and on Wednesday in the "Children's Hour" and after 10 o'clock again. It seems pretty evident, therefore, that the trouble came from outside the town on the high-power set.

Your correspondent, Mr. Parsons, of Winchester, judging by the tone of his letter, is either a transmitter or has some technical knowledge of these matters, and seems to be uncannily certain of his own deductions. He seems to have overlooked enlightening us as to the main factor in the situation, however, *viz.*, why, if the signals came from an Admiralty Station, no call sign was used, and under what conceivable circumstances an Admiralty Station would send out a repetition of P.1's for hours at a stretch.

However, having focussed attention on this matter, the full weight of the evidence has been transmitted to Bournemouth for the B.B.C.'s perusal, together with the suggestion that some unauthorised person may have gained access to a high-powered set between hours. They will, no doubt, take such action as they think fit to prevent a repetition of the nuisance, if they have not already done so, as I note there was no interference yesterday.

Thanking you for your valuable help in this matter.—Yours faithfully,

(Signed) D. S. BAKER.

"West Brook," Millbrook Road.

SIR,—May I again beg space to enlighten numerous amateurs with regard to the interference they have had to contend with within the last few days.

It is the custom of high-power stations to measure "field strength," etc., at certain periods with a view to gaining further knowledge of the behaviour of waves radiated, absorption factors, harmonic phenomena and the like. This, of course, needs more than one station, the chief of which is the transmitter. It may be also that a new type of transmitter required testing. This necessitates the station sending for a given period. For different wave-lengths and powers different symbols are used, the one we have heard being P.1 (P one).

This symbol was sent out by a station which did give a call sign, namely, "BYC," hence "BYC" has been experimenting again, and we, through being in close proximity to such a high-powered station, have been the victims of harmonic interference. As an experimenter I find great pleasure in trying to devise some means whereby these harmonic effects may be eliminated during such tests as we have just experienced.

Who knows but what these experiments were being carried out for the benefit of amateurs in the future ?—Yours, etc.,

(Signed) ALBERT PARSONS.

65, Cromwell Road, Winchester.

February 9, 1924.

SIR,—The thanks of all wireless enthusiasts are due to Mr. Baker for focussing and consolidating attention in the proper quarter to the recent disturbances. It is only by prompt and energetic action that this sort of thing can ever be eradicated and wireless made enjoyably possible. If an Admiralty station was at the bottom of the trouble, as per Mr. Carter's suggestion, the B.B.C. will no doubt arrange with them in future to try new apparatus at some other time than during the few hours that thousands, probably millions, of people are enjoying a harmless amusement.—Yours, etc.,

R. M.

Bassett.

February 11, 1924.

The visit to France of Mr. Percy Hiram Maxim, President of the American Radio Relay League, resulted in the formation of an International Amateur Radio Association. Several important meetings and dinners were held, at which many well-known British and Continental amateurs and several radio engineers were present. In the upper photo British 2NM, 2KW, and 2SH will be recognised by many readers, while in the lower photo Mr. Maxim is sitting third from the left in the foreground and General Ferrié will be noticed second from the left facing camera.

Business Brevities.

A Combined Frame Aerial and Mast.

We have just received from the Abbey Engineering Works of Watton, Norfolk, some details of their new frame aerial, which is so constructed as to enable it to be fixed to a mast. It is, of course, capable of being rotated so as to point in any direction, and can, therefore, be used for directional work. The mast can be supplied alone for indoor use, for fixing to existing masts, or complete with a mast of any desired length. The idea appeals to us as being of particular value to those who are unable to employ a long aerial. The frame can be used, of course, as a closed loop, or when used on the top of a mast chiefly as a capacity. When used on a short chimney mast it should be particularly free from screening effects, although the

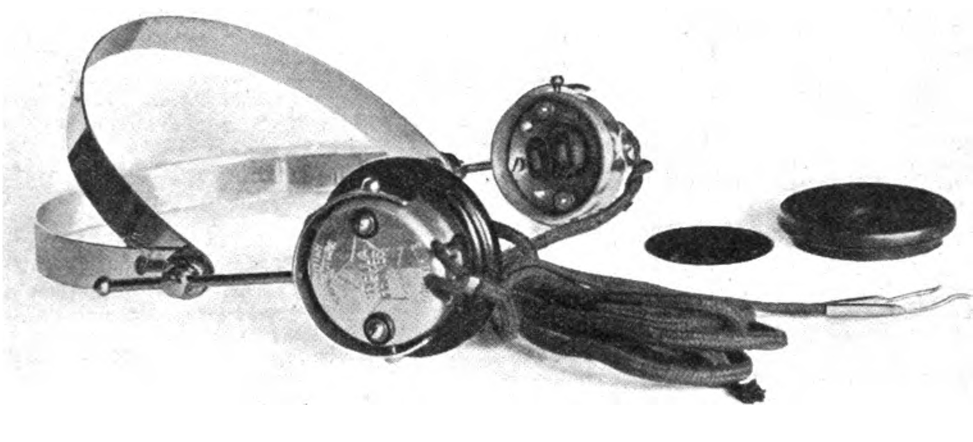


Fig. 1.—Illustrating the construction of the Stella Phones.

mast and leads would introduce a local error in bearings if employed for accurate D.F. work. The frame is supplied at 40s. ready for fixing to an existing mast, or for indoor use. We hope to be able to report on some actual tests very shortly.

* * *

STELLA PHONES.

Telephone receivers are already counted by their dozens, and the "Stella Phones" are the latest arrival amongst the ever-swelling ranks. Their most attractive feature is the extremely moderate retail price of 17s. 6d., and this at first made us rather sceptical of their quality and performance. However, as far as we can remember, we have not tested a better instrument at the price. It would be unfair, of course, to compare them with the high-priced phones which the experimenter is accustomed to use, but on test they were found electrically to come very near to our standard, both quality and volume of speech being good. The appearance can be gathered from the accompanying photograph, in which the head-band and method of mounting may be seen, which results in comfort, even if worn for long periods. The magnetic system is similar to that employed in the well-known low resistance "watch" receivers.

* * *

THE H.C.W. TRANSFORMER.

We have always been rather prone to doubt the efficiency of a low priced intervalve transformer, but the H.C.W. has caused us to modify our views somewhat, as it is certainly an exception to the rule. The H.C.W. transformer which has been placed on the market by S. T. Hosken, of 153, Fleet Street, London, E.C., is of the shell type having a core of soft annealed iron wire. This is enclosed in a steel tube which is closed at one end with a brass plate and at the other by an ebonite terminal board. The general appearance can be gathered from the accompanying illustration. The ratio of the windings is 1 to 5, there being 5,000 turns on the primary. The performance is remarkably good. It was first tested as a first stage amplifier on broadcasting and far greater amplification was obtained than expected, without any appreciable distortion. The transformer was then placed in a power stage and showed no sign of saturation, the quality and degree of amplification being as good as before. As a general purpose transformer we can thoroughly recommend it to our readers who should find it

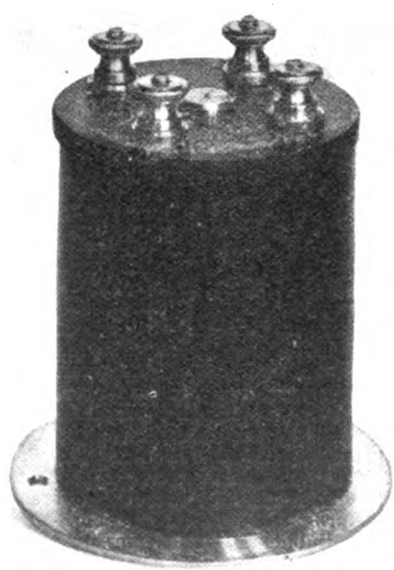


Fig. 2.—The H.C.W. Transformer.

extremely good value, especially in view of the moderate price of 15s. 6d.

* * *

St. Ivel Crystal.

It is quite a relief to find a crystal of the galena variety which is not another " ite." The British General Radio Co., Ltd., of 74, Hindford, Yeovil, have sent us a specimen of their St. Ivel crystal which, it is claimed, possesses the unique feature of being washable. When first tested we found it quite sensitive, not in one place only, but practically all over. We were also interested to note that it was not particularly susceptible to pressure. We next examined the effect of washing. A definite amount of energy was introduced into a tuned circuit, and the crystal was connected across the circuit and the rectified current measured. The crystal was then removed, made thoroughly dusty and dirty, washed, dried, and replaced. The amount of rectified current was found to be unaltered, and when subsequently tested on broadcast signals, was found to be quite satisfactory. A specimen of the crystal is sent post free for 1s. 9d.

A Condenser Brush.—Messrs. Goswell Engineering Co., Ltd., have produced a combined panel and condenser brush which consists essentially of a small brush and a pipe cleaner in the form of a loop fixed to the handle. The device should be of great use to those who allow their condensers to become dusty, and should also prove of general utility. The address of the manufacturers is 12A; Pentonville Road, London, N.1.

* * *

The Eagle Engineering Co., Ltd.

We have received a new catalogue from the Eagle Engineering Co., Ltd., and in addition to several broadcast receivers we note a large variety of useful components which should make the list of value to our readers.

* * *

The Library Press.

We have been asked to announce that the Library Press have just moved into larger premises, the new address being 83, Southwark Street, London, S.E.1.

Experimental Notes and News.

The Radio Society of Great Britain and the Radio Transmitters' Society.

On Tuesday, February 26, at the Headquarters of the R.S.G.B., at 53, Victoria Street, London, S.W., a joint meeting between members of the Committees of the Radio Transmitters' Society and of the Transmitting and Relay Section of the R.S.G.B. was held. This meeting arose out of the resolution recently passed by the members of the Radio Transmitters' Society in general meeting, when the principle of amalgamation with the Transmitting and Relay Section was approved. The business done at the meeting was of a preliminary nature, the main object being to settle the officers and devise the machinery for the carrying on jointly of the work which hitherto had been done by the two bodies.

On the proposition of Dr. W. H. Eccles Captain Ian Fraser was appointed chairman of the Amalgamated Committee, and Mr. Gerald Marcuse was appointed honorary secretary. Mr. W. Corsham and Mr. D. K. Alford accepted the office of joint traffic managers, and were asked to prepare a scheme for consideration at the next Committee meeting to be held on Tuesday, March 11, for the carrying on and development of transmission tests, calibration signals, etc. It was agreed that the Committee should continue the series of successful lectures which under the auspices of the Radio Transmitters' Society had been regularly held, and the Secretary was asked to book a room at the Institute of Electrical Engineers for March 14 and 28, and April 25. It is not possible to announce in time for publication the names of the lecturers on these occasions, but notices will be served upon the members in due course.

As regards finance, it was reported that the Radio Transmitters' Society had a substantial balance to hand over for the use of the new Committee, and a sub-committee, consisting of Messrs. Maurice Child, E. J. Simmonds and H. S. Walker (honorary treasurer of the R.T.S.) was appointed to advise the Committee as to the best method of adjusting all outstanding matters relating to subscriptions, etc.

General satisfaction was expressed at the prospect of future harmonious working under the auspices of the R.S.G.B., and the Committee were confident that, after a brief delay to allow all matters under negotiation to be properly settled, the new and enlarged Transmitting and Relay Section of the R.S.G.B. would be able to offer its members more adequate facilities and stronger representation than had hitherto been available.

Manchester and District Radio Transmitters' Society.

The inaugural meeting of the above Society was recently held at the Grand Hotel, Aytoun Street, Manchester. There was an attendance of twenty-five.

After Mr. W. C. Barraclough (5AJ) had been elected to the chair, a few remarks were made by Mr. W. R. Burne (2KW), and correspondence read relating to the formation of the Society. Finally, it was decided unanimously that the Society be formed. Between fifteen and twenty gentlemen were unable to attend the meeting, but expressed their willingness to join the Society.

This gives a membership of nearly fifty, and it is hoped that all who hold transmitting permits will avail themselves of this unique opportunity afforded them for forming one strong Society for transmitting amateurs in the Manchester district.

The following officers were appointed :—Hon. secretary, Mr. W. R. Burne (2KW) ; assistant hon.

secretary, Mr. A. Rainford (61K); while the duties of the hon. treasurer and chairman were entrusted to the able care of Mr. W. C. Barraclough (5AJ).

The following gentlemen were asked to serve on a temporary committee:—Messrs. Stevenson (5IK), Cross (2RN), Davies (2PC), Sparrow (2TR), Cash (2GW), Chadwick (2WT), Bailey (2UF), Cropper (6XY) and Bolt (6BB).

The Hon. Secretary will be pleased to hear from all who, possessing transmitting permits, would care to join the Society, if they would write to "Springfield," Thorold Grove, Sale. The Committee would especially welcome, at the next extraordinary general meeting, which commences at 7.30 p.m. prompt, on Tuesday, March 11, 1924, at the Grand Hotel, Aytoun Street, Piccadilly, Manchester, any newcomers.

It is intended to hold the meetings about once a month, when speakers of special interest to holders of transmitting permits will be asked to deliver lectures on subjects dear to the hearts of the transmitting amateur.

Board of Radio and Scientific Research.

A new body has been formed, to be known as the "Board of Radio and Scientific Research."

The objects of this body are to carry out deep and serious investigations into problems of a radio and scientific nature, and to provide such societies as desire to avail themselves with the results of these investigations in the form of papers, lectures, etc., free of charge.

Notice will be given in the Radio Press in due course when such offer is ready, and those interested should write to the Hon. Secretary, "Kitray," 132, Handcroft Road, W. Croydon, Surrey.

Experiments have recently been carried out on the Great Western Railway to demonstrate the feasibility of the reception of broadcasting on a train travelling at 80 miles per hour. A double wire indoor aerial laid along the roof of a corridor coach was used. It is understood that the success of the experiment will probably lead to the regular adoption of reception equipment on long-distance trains, passengers being able to use the 'phones on payment of a small charge.

* * *

The German Government has under consideration a proposal to assume the monopoly of the wireless industry, both as regards the manufacture of receiving apparatus and the operation of broadcasting stations.

* * *

Senatore Marconi is reported to have made considerable progress in his experiment on directional wireless transmission. He stated in a recent interview that he had already succeeded in sending messages on a "beam" over a distance of 2,000 miles.

* * *

The White Star liner *Olympic* has been fitted with an apparatus which has enabled messages to be sent automatically at 90 words a minute from the ship 700 miles from land to Devizes, and thence to the G.P.O., London, where they were printed in ordinary roman letters. This is the first time that such transmission has been employed for sending messages from ship to shore.

* * *

Mr. Dan Godfrey, lecturing recently, at Sheffield, on the broadcasting of music, stated that the great difficulty in transmitting drum music had been overcome by standing the drums on raw rubber. To get effective results with a choral society of about seventy performers, it was necessary for them to stand with their backs towards the microphone, and the voices then rebounded off the walls into the microphone, so minimising the vibrations.

* * *

The following call signs have been adopted for the new relay stations:—Edinburgh, 2EH; Hull, 2HU; Leeds, 2LS; Liverpool, 6LV; Plymouth, 5PY.

* * *

The first broadcasting station in Australia has been erected in Sydney by Messrs. Farmer & Co., and a service comprising music, vocal items, news, lectures and theatrical performances is already in operation. The Government issue licences to broadcasting companies, who must deposit £1,000 as a surety that they will continue to operate for five years; the company is then allotted a definite wave-length. Intending listeners-in must take out a Government licence at the cost of 10s., and also subscribe to any company whose programme they desire to receive. The receiving sets will be sealed, so that no wave-length can be tuned in except that of the company to which the subscription has been paid. Genuine experimenters, however, are permitted to use unsealed sets. Messrs. Farmer have obtained the first licence, and operated on a wave-length of 1,100 metres. The station is situated eight miles from Sydney, at Willoughby, and is known as 2FC.

* * *

Mr. Nikola Tesla, well known in connection with high-frequency electrical research, is reported as claiming a new discovery of a system of electrical power transmission through the earth. He states that loss in transmission to the greatest terrestrial distance, say 12,000 miles, will not amount to more than a quarter of one per cent., as against 20 per cent. loss in normal transmission through cables.

* * *

The opening of Plymouth Broadcasting Station, 5PY, was fixed for March 28, so it is doubtless in full operation by the time these notes appear.

* * *

Trouble has been caused in South Wales by radio aerials falling across overhead electricity distributing lines. In one instance an aerial in course of erection was allowed to fall across a 400-volt overhead power line, but fortunately the safety device in the local sub-station operated and the line was made "dead," otherwise the erectors would have received a severe shock.

* * *

The Pope is one of the latest converts to the benefits of wireless. A receiving installation has just been installed at the Vatican.

* * *

Seven high-powered wireless stations are to be erected in the West Indies on the islands of St. Kitts, Antigua, Dominica, St. Lucia, St. Vincent, Grenada and Barbados, the crescent-shaped archipelago which flanks the Caribbean.

Recent Wireless Publications.

Figures after the title of each publication indicate Volume and Number of Publication containing the article. Where only one number is given, this indicates the serial number of the publication.

ABBREVIATIONS OF TITLES OF JOURNALS USED IN THE BIBLIOGRAPHY.

Amer. Acad.—American Academy of Arts and Sciences.
Am.I.E.E. J.—Journal of American Institute of Electrical Engineers.
Ann. d. Physik—Annalen der Physik.
Boll. Radiotel.—Bolletino Radiotelegraphico.
Elec. J.—Electric Journal.
El. Rev.—Electrical Review.
El. Times.—Electrical Times.
El. World.—Electrical World.
Electn.—Electrician.
Frank. Inst. J.—Journal of the Franklin Institute.
Gen. El. Rev.—General Electric Review.
Inst. El. Eng. J.—Journal of the Institute of Electrical Engineers.
Inst. Rad. Eng. Proc.—Proceedings of the Institute of Radio Engineers.
Jahrb. d. drahtl. Tel.—Jahrbuch der drahtlosen Teleg, etc.
Mod. W.—Modern Wireless.
Nature—Nature.
Onde El.—L'Onde Electrique.
Phil. Mag.—Philosophical Magazine.
Phil. Trans.—Philosophical Transactions.
Phys. Rev.—Physical Review.
Phys. Soc. J.—Journal of Physical Society of London.
Q.S.T.—Q.S.T.
R. Elec.—Radio Electricité.
Roy. Soc. Proc.—Proceedings of the Royal Society.
Sci. Abs.—Science Abstracts.
T.S.F.—Telegraphie sans fils, Revue Mensuelle.
Teleg. without Wires, Russia—Telegraphy without Wire, Nijni Novgorod.
W. Age—Wireless Age.
W. Trader—Wireless Trader.
W. World—Wireless World and Radio Review.

I.—TRANSMISSION.

ANTENNA SERIES CONDENSERS, GOOD AND BAD.—S. Kruse (*Q.S.T.*, 7, 8).

SOME GOOD LEAD-IN INSULATORS.—S. Kruse (*Q.S.T.*, 7, 8).

LA MODULATION EN TÉLÉPHONIE SANS FIL AVEC DES MODULATEURS MAGNETIQUES.—Marius Latour (*R. Elec.* 5, 54).

TRANSATLANTIC RADIO - TELEPHONY.—Capt. St. Clair-Finlay, B.Sc. (*Exp. W.*, 1, 6).

II.—RECEPTION.

RADIO FREQUENCY AMPLIFICATION.—Stuart Ballantine (*Q.S.T.*, 7, 8).

HOMODYNE.—F. M. Colebrook, B.Sc. (*W. World*, 236).

ALIMENTATION DES RÉCEPTEURS RADIOPHONIQUES PAR LE COURANT ALTERNATIF DU SECTEUR.—I. Podliasky (*R. Elec.* 5, 54).

LE MEILLEUR RÉCEPTEUR POUR TOUTES LONGEURS D'ONDE (80 À 25,000 MÈTRES).—J. Reyt (*R. Elec.* 5, 54).

HOWLING IN RESISTANCE AMPLIFIERS.—F. M. Colebrook, B.Sc. (*Exp. W.*, 1, 6).

THE TELEPHONE RECEIVER AND ITS APPLICATION TO WIRELESS RECEIVING CIRCUITS.—Alexander J. Gayes (*Exp. W.*, 1, 6).

THE MANUFACTURE OF HIGH RESISTANCES FOR WIRELESS RECEIVING CIRCUITS (*Exp. W.*, 1, 6).

THE REFLEX.—(*Exp. W.*, 1, 6.)

III.—MEASUREMENT AND CALIBRATION.

A METHOD FOR ACCURATE FREQUENCY CALIBRATION.—N. V. Kipping (*W. World*, 236).

THE MEASUREMENT OF LOW-FREQUENCY AMPLIFICATION.—R. L. Smith-Rose, Ph.D. (*W. World*, 238 and 239).

HIGH - FREQUENCY RESISTANCE.—H. Andrewes, B.Sc. (*Exp. W.*, 1, 6).

IV.—THEORY AND CALCULATIONS.

FORMULES APPLICABLES AU CALCUL DE L'INFLUENCE DE LA NATURE DU SOL ET DE L'ANGLE D'INCIDENCE DES ONDES ELECTROMAGNÉTIQUES SUR LE FONCTIONNEMENT DES ANTENNES ET DES CADRES DE RÉCEPTION.—Léon Bouthillon (*R. Elec.* 5, 54).

V.—GENERAL.

ON COMPARING VALVES.—P. K. Turner (*W. Trader*, 2, 13).

HOW ANTENNÆ WORK.—John L. Reinartz (*Q.S.T.*, 7, 8).

THE OPERATION OF CLOSE COUPLED TRANSFORMERS.—W. P. Powers (*R. News*, 5, 9).

A.C. MAINS FOR FILAMENT HEATING AND PLATE CURRENT.—E. H. Turle (*W. World*, 236).

THE SELECTION OF TAPPING POINTS IN INDUCTANCE COILS.—A. H. Burnand (*W. World*, 236).

AN IMPROVEMENT IN FRAME AERIAL CONNECTIONS.—W. B. Mellam and A. O. Schwald, B.Sc. (*W. World*, 237).

ANOTHER USE OF THE NEON LAMP.—J. F. Payne (*W. World*, 237).

A PRACTICAL DEMONSTRATION OF SOME APPLICATIONS OF THE CATHODE RAY OSCILLOGRAPH.—N. V. Kipping (*W. World*, 238).

THE TESTING OF L.F. TRANSFORMER WINDINGS.—F. L. Devereux, B.Sc. (*W. World*, 239).

FILAMENT CURRENT FROM THE MAINS.—(*W. World*, 239.)

TELEVISION.—Nicholas Langer (*W. World*, 240).

UNE APPLICATION INDUSTRIELLE DE LA HAUTE FREQUENCE: LES FOURS ELECTRIQUES.—P. Dastouet (*R. Elec.*, 5, 54).

WIRELESS FOR POLICE WORK.—(*Electn.*, 2391.)

DIRECTION-FINDING.—Cmdr. J. A. Slee (*Electn.*, 2391).

DIRECTIVE RADIO-TELEGRAPHY AND TELEPHONY.—R. L. Smith-Rose, Ph.D. (*Exp. W.*, 1, 6).

THE SELF-CAPACITY OF COILS.—J. H. Reyner, B.Sc. (*Exp. W.*, 1, 6).

Experimental Wireless

A JOURNAL OF RADIO RESEARCH AND PROGRESS

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Experimental Topics.

Amateur Transmission.

Reception in the neighbourhood of both 200 and 440 metres shows that during the last six months the number of amateur experimenters now in possession of transmission licences has increased enormously, much more, in fact, than we should have expected. Is it, we wonder, a sign of less stringent examination on the part of the General Post Office or is it the result of a higher standard of qualifications amongst amateurs? We have no means of answering the questions other than by listening to the various transmissions which are always so prolific. Frankly we frequently cannot see the value of many of the so-called tests which are conducted and it is hard not to believe that far more knowledge would be gained by the use of an artificial aerial circuit instead of the usual radiating system. Many experimenters seem to forget that transmission permits are granted exclusively for experimental work and not primarily for the purposes of communication. We refer here to much of the unnecessary interference which is caused by futile "DX" work. Amateur transmission in America, for example, is essentially organised for the relaying of messages. In England with suitable transmission and reception gear it is possible to get from Land's End to John o' Groats on ten watts and any British relaying scheme would be almost *prima facie* evidence of inefficiency. Moreover, we understand that the authorities are not particularly interested in such an undertaking. It must not be imagined, however, that we look with any disdain upon the so-called "DX" work, for admittedly it can be of extreme value. Take for example the case of an experimenter who is testing the radiating properties of various aerial systems. Nothing is more helpful than to receive a series of accurate reports on signal strength from a number of scattered stations at great distances, but when one hears night after night "Test," "Test," "Test," and even "CQ," which, of course is strictly forbidden for amateur use, we feel that the persons responsible are not really helping the amateur in his relationship with the Post Office.

Wireless Terminology.

Because wireless is comparatively a new science it is not surprising to find that there is a considerable difference of opinion concerning many of the more common terms used in radio engineering. The British Electrical Standards have recently issued a suggested list of terms and definitions, and once again we refer our readers to this pamphlet, No. 166. At the present time we find that in many cases several names are given to one particular object and this can only lead to confusion. There is, of course, no real international nomenclature, nor even any recognised standard conventional representations of wireless apparatus,

but there is absolutely no need to mix with our own terminology words culled from other countries. We do not refer particularly to scientific treatises, but rather to contributions to the wireless press in general. Such terms as "feed back," for example, are quite unnecessarily finding their way into our literature, but we have our own equivalent expression, and surely when we are writing in English there can be no objection to using English terminology.

The Location of the London Broadcasting Station.

One of our esteemed contemporaries in an editorial comment draws the attention of their readers to the location of the London Broadcasting Station, a subject which has been under consideration by the British Broadcasting Co. for some time. As everyone knows the main part of the 2LO gear is situated at the present time on the top floor of the Marconi Company's building in the Strand and the fact that it should be so intimately connected with one particular member of the British Broadcasting Company is no doubt responsible for the decision to move the station at the earliest possible moment. Rumour has it that a proposal has been put forward to move the station to a very well-known building in the West End and our contemporary suggests that it would be equally undesirable for the new London station to be associated with any building "controlled by another interest where rivalry in commercial enterprise is even stronger than in the wireless industry." As a satisfactory solution to the problem they suggest that it would be advisable from all points of view if the British Broadcasting Company were to find a suitable site and become the sole owners. This is certainly very wise counsel, but we are afraid that it is easier said than done. The conditions determining a suitable site are both numerous and hard to fulfil. In the first place the studios must be readily accessible and accordingly must occupy some central position. If the station is to be in the same building as the studio it may be extremely difficult to arrange for an efficient radiating system. To build the station at any considerable distance from the studios leads to certain difficulties, particularly in a crowded district such as the Metropolis as line troubles are sure to be increased. Also of course the fact that a large amount of simultaneous broadcasting is carried out from 2LO at once complicates matters as the relay lines must follow suitable routes to the main station. Obviously then, the problem is not an easy one and we are surely not justified in criticising too severely any suggestions that are put forward. It is not likely that the British Broadcasting Company will make any rapid decisions without giving due consideration to every point which is involved.

Distribution of Components.

As a result of a considerable number of statements made by many of our regular readers we have come to the conclusion that there must be some little hitch in the methods employed either in the distribution or manufacutre of certain components which have been placed upon the market during the last few months. It appears to be no exaggeration to say that some of them are almost unprocurable, which is indeed strange, in view of the fact that the components are repeatedly and universally advertised, and accordingly the prospective purchaser is justly led to believe that immediate supplies are available. We have not sufficient knowledge of the facts to suggest the possible cause of delay, but feel that it is a subject of considerable importance to the manufacturer and experimenter alike. At the present time wireless sales are still in the ascendant. The demand is abnormal, and consequently the individual requirements of a customer are liable to be lost sight of, while the manufacturer is all concerned with increased production. At the same time, however, the experimenter looks for service, and it is only natural for him to use those components which can be obtained with the minimum of trouble and delay. Surely this is a point which the manufacturer would do well to remember, for although several dissatisfied customers are relatively of no importance at the present time, conditions will be very different when the demand for wireless goods is stabilised. On the whole, we may say that the majority of manufacturers give their clients excellent service, but just now there seems to be some little trouble. Perhaps this is only a passing phase and is capable of reasonable explanation.

Antenna Constants—Capacity.

By GORDON WILLIAM INGRAM, B.Sc., *Maintenance Engineer, B.B.C.*

THE simplest method of calculating the capacity of a radio-telegraphic antenna system is first to evaluate the average potential of the system, due to the charge of electric energy applied to that antenna.

Experimental data shows that if a single straight aerial wire, either horizontal or vertical, be charged to a potential above that of earth, then the electric charge will not be uniformly distributed over the surface of the wire. The greatest density of charge is found

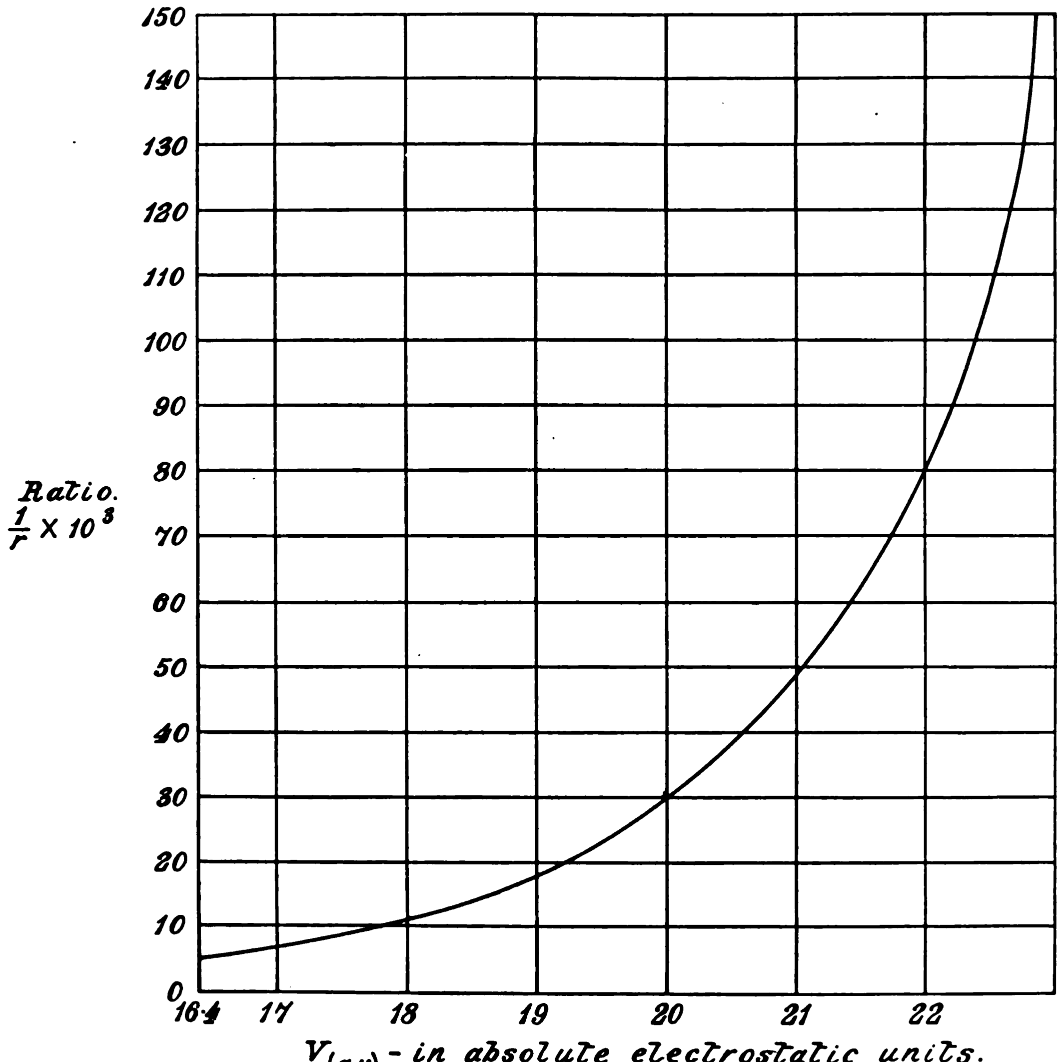

Fig. 1.—Single wire antennae $V_{(av)}$ where σ=1 unit per sq. cm.

$V_{(av)} = 4\ r\ (\log_e \frac{l}{r} - 0{\cdot}307)$ in absolute electrostatic units.

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at the two ends of the wire or aerial system, but for the purposes of calculation it is simpler to find a case where uniform distri-

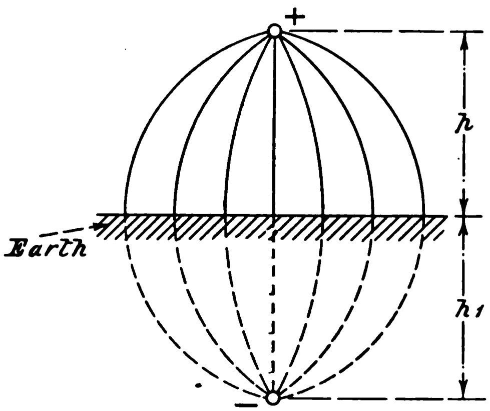


Fig. 2.—Illustrating the image of the aerial.

bution obtains, in which case the potential variation from point to point can be readily calculated.

Since, in practice, uniform distribution does not obtain in a continuous wire, assume that the antenna system is composed of a fairly large number of short pieces of wire, say 1 cm. long, placed end to end, and insulated one from another; then uniform distribution is possible along the whole length of the antenna. When the value of the charge in each of these insulated sections is known the insulation between them is removed, thus a continuous conductor is formed, and the current will flow from the centre sections towards the ends of the wire, until we can say that the average potential of the system is equal to the potential of any one of the insulated sections which was found previously—that is to say, that the total charge in the antenna composed of the insulated sections is exactly equal to the total charge in the continuous wire system.

From the value of the average potential of the system we may calculate the capacity of the antenna by using the formula:

$C=\frac{Q}{V}$ where C is the capacity due to total charge Q at potential V.

It is true to say that the capacity of any antenna depends not only on the charging potential, and its dimensions, but also on its distance from earth, which latter quantity can be considered analogous to the dielectric thickness in an ordinary plate condenser.

In Professor G. W. O. Howe's calculations, the average potential is obtained first taking the distance of earth as infinity, extra potential being added to allow for the proximity of earth.

Straight-Wire Antenna.

In a straight-wire antenna having a single strand the average potential is approximately given by:

$$V_{(av)}=4\pi r\sigma\left(\log_\epsilon \frac{l}{r}-0{\cdot}307\right)$$

where r = radius of the wire in cms.
l = length of the wire in cms.
and σ = surface density of the charge in absolute electrostatic units per sq. cm.

The accurate expression is:

$$V_{(av)}=4\pi r\sigma\left(\sinh^{-1}\frac{l}{r}-\sqrt{1+\frac{r^2}{l^2}}+\frac{r}{l}\right)$$

but the difference between the two expressions is, for all practical purposes, negligible. The curve, Fig. 1, provides a ready means of evaluation of $V_{(av)}$ for a single-wire antenna charged with one unit per sq. cm. at distance infinity from earth.

Multiple-Wire Antenna.

The average potential of a flat-topped

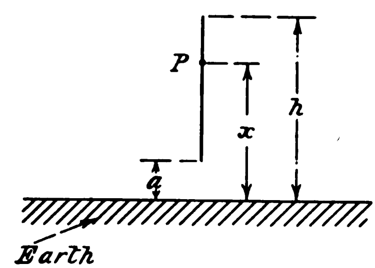


Fig. 3.—The conditions for a vertical wire.

multiple-wire antenna system is approximately given by the formula:

$$V_{(av)}=4\pi r\sigma\left[n\left(\log_\epsilon \frac{l}{d}\right)+\log_\epsilon \frac{d}{r}-B\right]$$

where n = total number of wires in the system
and d = distance between them in centimetres.
B is a factor variant with the number of wires in the antenna.

n	B	n	B
2	0	7	4·85
3	0·46	8	6·40
4	1·24	9	8·06
5	2·26	10	9·80
6	3·48	11	11·65
		12	13·58

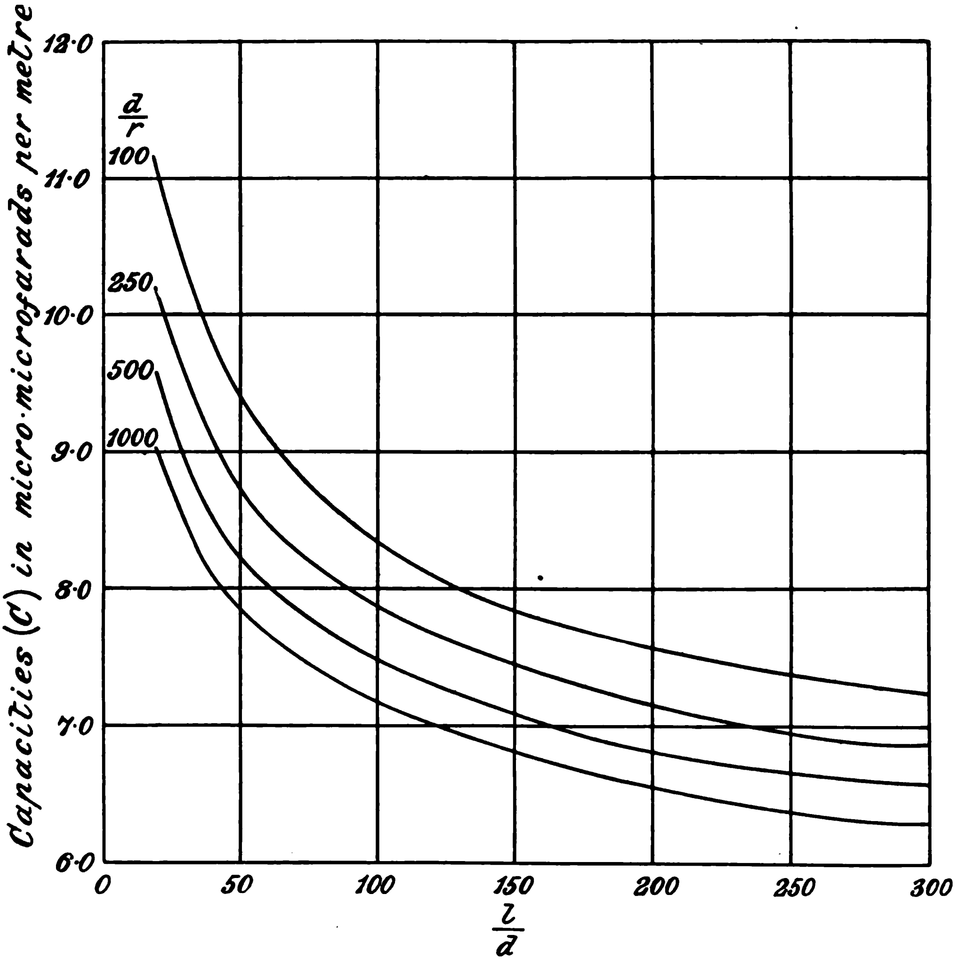


Fig. 4.—Capacities of two-wire (parallel) antennae—neglecting the influence of earth.

Ratio $\frac{d}{r}$ where d=distance between the wires in cms.

and r=radius of wire in cms.

Now, $C=\frac{Q}{V}$ where Q=the total charge

and V=the charging potential.

By application of the formulæ we already investigated the above curves have been drawn.

Four-Wire Cage Antenna.

Where the wires occupy the four sides of a square of side d, then for assumed uniformly distributed charge the average potential of any wire due to its own charge:

$$V_{(av)}=4\pi r\sigma\left(\log_\varepsilon\frac{l}{r}-0{\cdot}307\right)$$

the potential due to the two nearest wires:

$$=2\times 4r\left(\sin h^{-1}\frac{l}{d}-\sqrt{\frac{d^2}{l^2}+\frac{d}{l}}\right)$$

and that due to the wire diagonally opposite:

$$=4\pi r\sigma\left(\sin h^{-1}\frac{l}{\sqrt{2}d}-\sqrt{1+\frac{2d^2}{l^2}+\frac{2d}{l}}\right)$$

therefore, the average potential of the whole system will be:

$$V_{(av)}=4\pi r\sigma$$

$$\left[\log_\varepsilon\frac{l}{r}-0{\cdot}307+2\left(\sin h^{-1}\frac{l}{d}-\sqrt{1+\frac{d^2}{l^2}+\frac{d}{l}}\right)\right.$$

$$\left.+\left(\sin h^{-1}\frac{l}{\sqrt{2d}}-\sqrt{1+\frac{2d^2}{l^2}+\frac{2d}{l}}\right)\right]$$

or, where Y is a factor,

$$V_{(av)}=4\pi r\sigma\left(\log_\varepsilon\frac{l}{r}+Y\right)$$

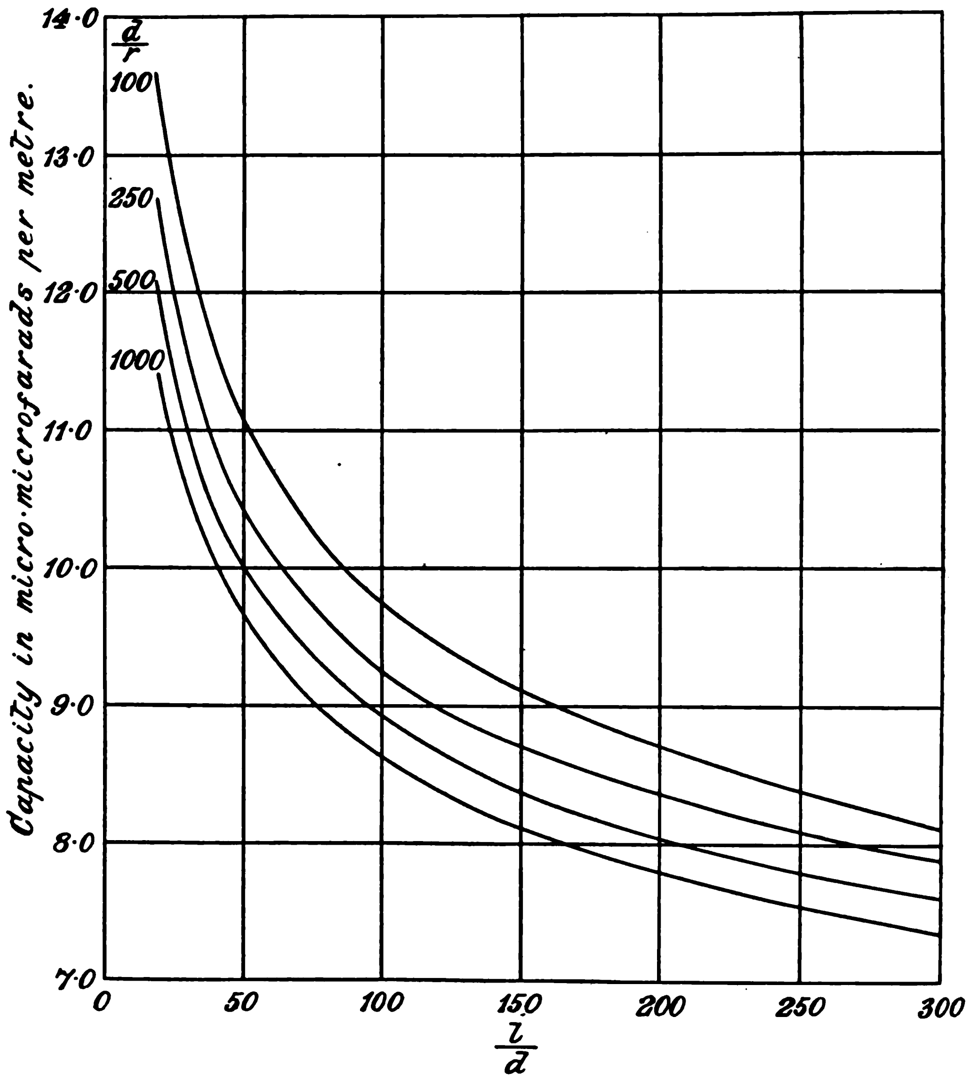


Fig. 5.—Capacity of three-wire (parallel) antennae. In micro-microfarads per metre.

Note.—The expression $\sqrt{1+\frac{d^2}{l^2}}=1$ practically with negligible error.

$\frac{l}{d}$	Y.
20	7·58
50	10·22
100	12·26
150	13·48
200	14·33

The Increase of Capacity, Due to Nearness to Earth, in a Horizontal Antenna.

When the antenna is not far from the earth, as is usually the case, its average potential will be lowered since negative charges are induced in the earth, hence the capacity is increased. Practically, the ratio of the height to the length of the system is large enough to enable us to take it that this induced negative charge is concentrated at a point in the centre of the electrical image of the antenna, where the earth is taken as the reflector, and $h=h_1$ (Fig. 2). Then :

$V_i=\frac{Q}{2h}$ where V_I is the potential due to the induced charge,

$$Q=2\pi r l\sigma.$$

Reducing $V_i=4\pi r\times\frac{1}{4h}=E$, a negative value.

Therefore, the formula for the average potential of a four-wire cage antenna becomes by correction for V_i:

$$V(av)=4\pi r\sigma\left(\log_e\frac{l}{r}+Y-2Vi\right)$$

Note.—

$$\frac{Q}{2h}=\frac{2\pi r l\sigma\times 4}{2h}=4\pi r\sigma\times\frac{l}{h}=4\pi r\sigma\times 2V_i$$

$$=4\pi r\sigma\left(\log_e\frac{l}{r}+Y-\frac{l}{h}\right)\text{OR } 4\pi r\sigma\left(\log_e\frac{l}{r}+Y+2E\right)$$

In a vertical wire the potential at point P, due to induced charge on the earth is given by

$$V_p=\log_e\frac{2\,(x+h)}{r}-\log_e\frac{2\,(x+a)}{r}$$

For the whole wire the average potential is given by:

$$V_{av}=\frac{1}{h}\log_e 2^{\,2\,(a+h)}\cdot\left(\frac{a}{h}\right)^{2a}.$$

$$\text{or } \frac{1}{h}\left\{2\,(a+h)\log_e 2+2a\log_e\left(\frac{a}{h}\right)\right\}.$$

Neglecting the second term since a is small $V_{av}=2\log_e{}^2=1\cdot386\times\sigma=1\cdot386\times$ charge per unit length.

Practically V_{av}=Charge per unit length expressed in absolute electrostatic units.

Now, since $C=\frac{Q}{V}$, where C is the capacity, Q is the total energy in the antenna, and V the average potential of the whole antenna, the capacity can be readily calculated.

Potential of a Wire due to a Parallel Charged Wire of Equal Length and the Potential of a Horizontal Wire due to Proximity to Earth-Unit Charge per Centimetre Length.

ABSOLUTE ELECTROSTATIC UNITS.

$\frac{l}{d}$	E.	$\frac{l}{d}$	E.	$\frac{l}{d}$	E.
0·5	0·48	8·0	3·78	30	6·27
1·0	0·94	8·5	3·88	40	6·81
1·5	1·32	9·0	4·00	50	7·26
2·0	1·64	10·0	4·20	75	8·05
2·5	1·94	11·	4·36	100	8·62
3·0	2·20	12·	4·52	200	9·98
3·5	2·42	13·	4·64	350	11·10
4·0	2·62	14·	4·80	500	11·81
4·5	2·82	15·	4·94	750	12·62
5·0	2·98	16·	5·06	1000	13·20
5·5	3·18	17·	5·18	1300	13·72
6·0	3·28	18·	5·28	2000	14·58
6·5	3·42	19·	5·38	4000	15·91
7·0	3·54	20·	5·46	8000	17·18
7·5	3·66				

Note.—C will be in electrostatic units when Q and V are given in those units. Electrostatic unit =0·906 micro-microfarads.

It is found that the potential of an antenna is reduced by proximity to masts, buildings, and is calculated by assuming the electrical image of the wire to be on the side of the wall or mast, or most remote from the antenna system—as an average potential is decreased it follows that the capacity is increased.

The tables following are taken from the paper by Prof. G. W. O. Howe, reference to whose works have already been made. Fig. IV gives these results in the form of curves from which the capacity in micro-microfarads per metre can be found for two, three, and four wire aerials.

TABLE 1.

TABLE OF CAPACITIES OF PARALLEL WIRE ANTENNAE (NEGLECTING INFLUENCE OF EARTH).

In micro-microfarads per metre.

No. of Wires.	$\frac{d}{r}$	$\frac{l}{d}$—20.	50.	100.	150.	300.
FIG. IV. 2.	100	11·14	9·41	8·35	7·84	7·24
	250	10·20	8·73	7·88	7·46	6·82
	500	9·60	8·29	7·51	7·12	6·55
	1000	9·05	7·88	7·19	6·82	6·26
FIG. V. 3.	100	13·60	11·15	9·78	9·15	8·20
	250	12·69	10·49	9·29	8·71	7·84
	500	12·07	10·06	8·94	8·40	7·61
	1000	11·48	9·66	8·63	8·14	7·39
4.	100	15·58	12·50	10·82	10·03	8·92
	250	14·60	11·88	10·35	9·64	8·60
	500	13·94	11·45	10·03	9·36	8·40

A New Capacity Microphone.

By D. F. STEDMAN, B.A.Sc.

We give below details of construction of a new type of capacity microphone which is easily made and is capable of giving excellent results. The sensivity is so great that little amplification is needed.

IN view of the recent interest in any type of microphone claiming to be a "high quality" instrument, the writer passes on his endeavours in this direction.

A perfect microphone must conform to quite a number of conditions, but slight deviation from any one of which produces serious defects, and the design of such a microphone must be considered in relation to the required characteristics. The most essential of these are :

1. No diaphragm resonance ;
2. No internal "chamber" resonance ;
3. Uniform sensitiveness for all frequencies—possibly allowing a slight increase at the extreme ends of the scale, partially compensating for the insensitiveness of the ear ;
4. No audio lag ;
5. Must have a linear characteristic.

Either of the first three produces a somewhat similar effect, the accentuation of a few notes in a bad case or a broader band of frequencies in a more usual case. Much of the "tin" which was audible at 11.30 arises here.

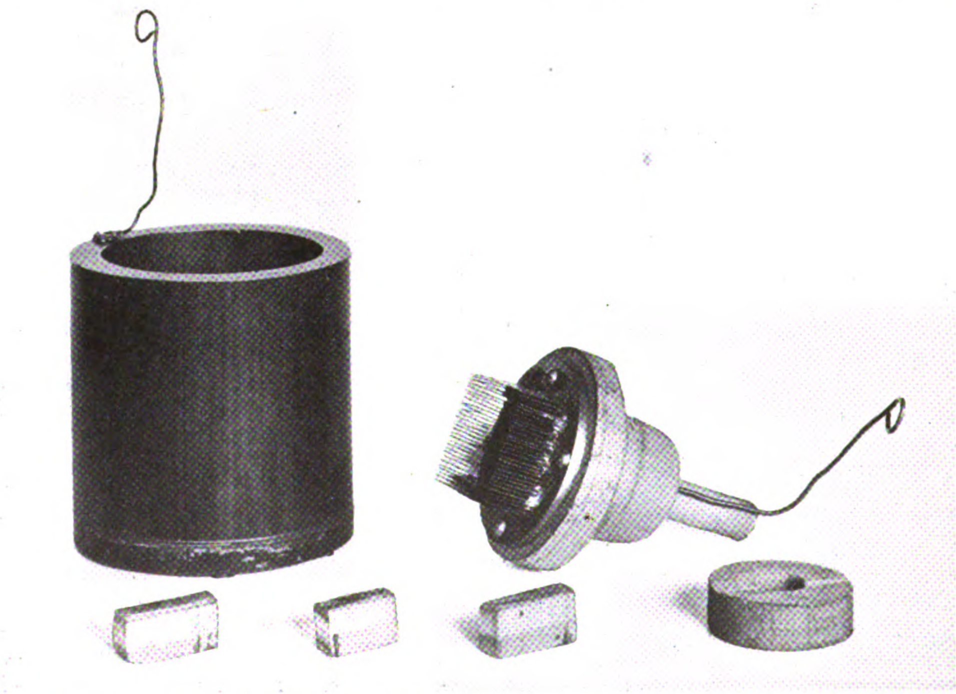


Fig. 1.—A near view of the various parts of an experimental microphone. Note the laminated back electrode.

If a microphone possesses an audio lag it cannot tell the difference between P and B, T and D, etc., that is, an explosive or sometimes an unsymmetrical wave shape is lost or badly distorted. The modified Post Office type, described in the January issue, would probably suffer rather badly here.

The diaphragm and moving system being sufficiently heavy to respond equally to all frequencies, requirements 1, 2, and 3 will now have a much larger inertia and would distort the explosive characters, *i.e.*, such a microphone would be reasonably close to the ideal for music, a complex of more or less related and sustained sine-waves, but for speech, a mass of unrelated transients, it is probably not so good, it was, in fact, sugested for the transmission of music.

A microphone may also have uniform sensitiveness and still not have a linear characteristic. That is, it will respond perfectly to all frequencies if applied alone, but if the diaphragm is temporarily disturbed from its position of rest by a relatively large low-frequency oscillation (and low-frequency oscillations are in general large, or they will not be heard) its sensitiveness will then be different. If a microphone has this defect it will produce a most curious effect. Consider that notes of frequencies of 100 and 800 pps. are applied simultaneous to a " non-linear " microphone. The diaphragm, while vibrating at 800 pps., passes through points of greater and less sensitiveness at 100 pps., *i.e.*, the 800 pps. will vary in intensity at 100 pps., introducing two other undesired notes—900 and 700 pps. While this case would probably not sound objectionable, it " isn't in the music," and it is easy to see how if all the notes present at an instant in an orchestral item are treated similarly a harshness would be produced with very slight curvature of the microphone characteristic, each note being interfered with by the resultants of the others. If n sine waves are present at any instant the number of resultants is n $(n-1)$, obviously a very large number, even if each one is hardly detectable the total result may be considerable.

The above requirements are common to all types of microphones, including capacity microphones, although being so simple they would seem to possess less inherent distortion, the production of an ideal microphone being a matter of design, principally of the diaphragm and the method of using it.

Items in the Design of such a Microphone.

Taking requirements 1 and 4 together, that it shall have no diaphragm resonance or audio lag (also largely a characteristic of the diaphragm). There are several ways of attacking this :

(*a*) Give an " ordinary " metal diaphragm a definite resonance frequency above the required band, by stretching it ; or
(*b*) A resonance frequency below the required band, by weighting it, or
(*c*) Use a diaphragm material that has no " will of its own," which will then move as part of the air.

Although method (*a*) may produce excellent results it is hardly suitable for amateur use, and it shares with (*b*) the serious defect of producing excessive insensitiveness. Method (*b*) also has the defect of needing such a large mass that considerable audio lag is introduced. This is noticeable even with a material as light as a silk diaphragm, the explosive characters being somewhat softened. It must be remembered that at 6,000 pps. the air column in immediate contact with the diaphragm, and actually effective in moving it, is only about half an inch long, and weighs but a few milligrams

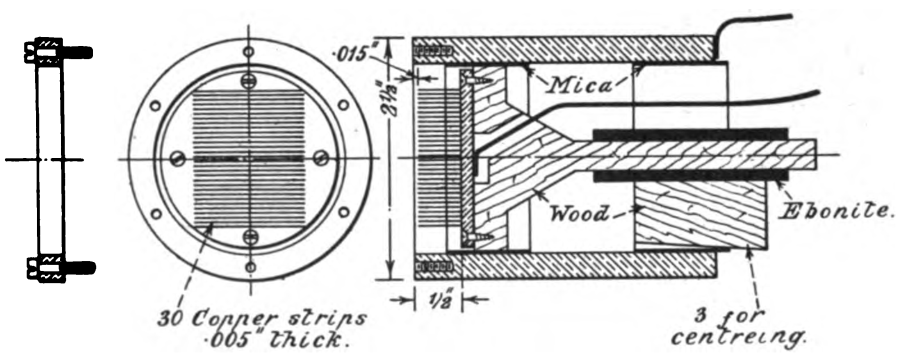


Fig. 2.—Constructional details of the microphone.

where the diaphragm usually weighs fractions of ounces. Method (*c*) seems far the simplest to the writer, and should produce equally good results.

The diaphragm materials tried were thin Jap silk with a gold leaf carefully stuck on one side (gold leaf, although so thin, is an excellent conductor, the resistance between two touch contacts about an inch apart is only about 2 ohms); a thin rubber film (toy balloon material) similarly treated with a gold leaf; and a gold leaf alone.

The silk being so light is rather difficult to mount flat and at the same time unstretched, also being very hygroscopic its tension varies considerably from day to day. In mounting the gold leaf on the silk or rubber support the front surface must be kept clean or it will not make contact, and, of course, every tear increases its resistance. A gold leaf diaphragm may seem very flimsy, but once mounted it is quite the reverse, provided one does not lay it down on a drawing-pin or test its tension by touching it. We have in this case the other extreme, the air is now the heavy body, and the diaphragm, although a good conductor, only weighs about 2 mg., and can obviously have no resonance or audio lag—in fact, it moves as if it were part of the air, a sound wave being transmitted, but not reflected.

The results obtained with these diaphragms is exactly as one would expect. The gold leaf is best both for purity of reproduction and is about twice as sensitive; the silk shows decided resonance at a low frequency (as it should not be deliberately stretched) but which varies from day to day, also due to its relatively large weight its sensitiveness falls somewhat at the higher frequencies; while the rubber is decidedly inferior in every way, except that its resonance is constant. Possibly a very thin film of collodion might be better as a support for the gold leaf, but it is perfectly satisfactory alone, and is not sensitive to draughts, the back of the microphone being nearly air-tight. Possibly Dutch metal might be a good substitute for the gold leaf.

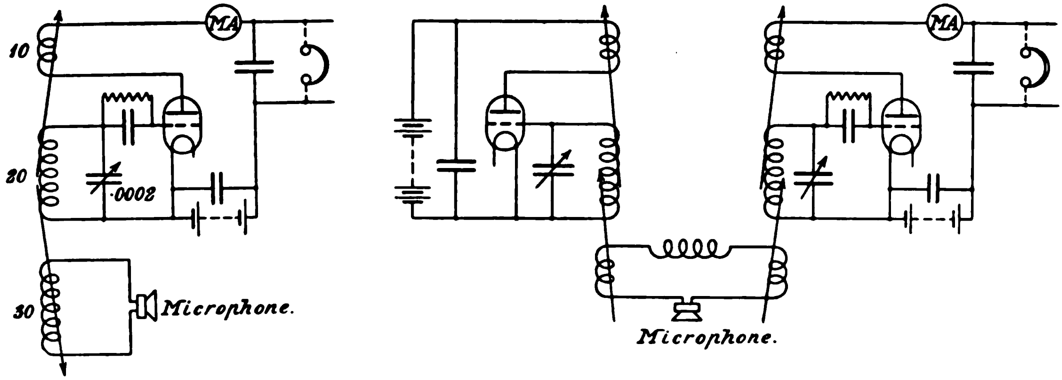


Fig. 3.—Two suitable absorption modulation arrangements for use with the microphone. The circuits are tuned approximately to 100 metres.

The other requirement in the design of the microphone is that it shall have no internal or chamber resonance. As the diameter is large compared with its depth it can only resonate as a "closed tube" with a wavelength of twice its depth, which, in this case, will not be a very strong resonance, as the

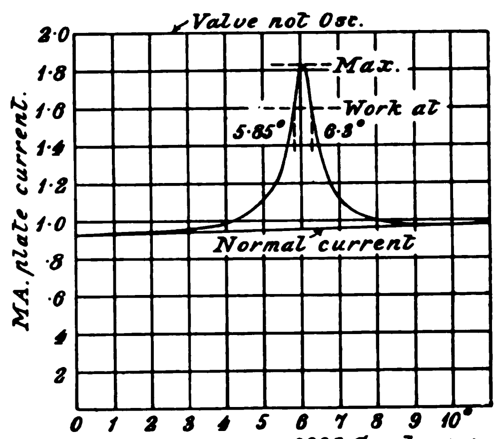


Fig. 4.—Curve showing correct position for operating microphone.

diaphragm is not capable of reflecting much of a sound wave. The air chamber can evidently have considerable depth without introducing audio resonance up to about ·75" (resonance frequency of 8,800). As compression of the internal air volume limits the movement of the diaphragm a reasonable amount of air space is desirable. On the other hand, the ratio of the capacity variation to total capacity is wanted as high as possible, therefore the device illustrated was used—a series of copper strips ·005" thick soldered edgewise on a brass plate, *i.e.*, the electrical surface is only ·015" behind the diaphragm (and could be closer still if desired), but the air depth is still ½". This simple arrangement makes it at least twice as sensitive as the simple brass plate close to the diaphragm. No difficulty is experienced in soldering on the strips if machine-cut strip is used and is clamped between cardboard strips during the process. This completes the electrical design of the microphone, the actual mechanical shape being merely a matter of convenience. The construction of the writer's microphone will be obvious from Figs. 1 and 2.

The next matter is the method of using it, which must conform to requirements 3 and 5 above, *i.e.*, it must not distort the uniform sensitiveness of the microphone, must provide a linear characteristic, and, at the same time, be as sensitive as possible (it will hardly be too sensitive).

A circuit is given in the January issue (p. 189), this is a frequency "modulation" the detection of which here depends on the selectivity of a crystal circuit (as is well known, an extremely unselective device and almost certainly non-linear), and detection of this frequency modulation with a valve is simply horrible at 100 metres in such close proximity to the oscillator. After considerable experiment on one or two valve circuits, using amplitude and frequency modulation, the two circuits given in Diagram 3 were far superior to any others tried. The two-valve is but very little more sensitive than the single-valve, and the simplicity of the single-valve circuit has much to recommend it. This is the circuit recommended, and Fig. 4 refers only to this circuit.

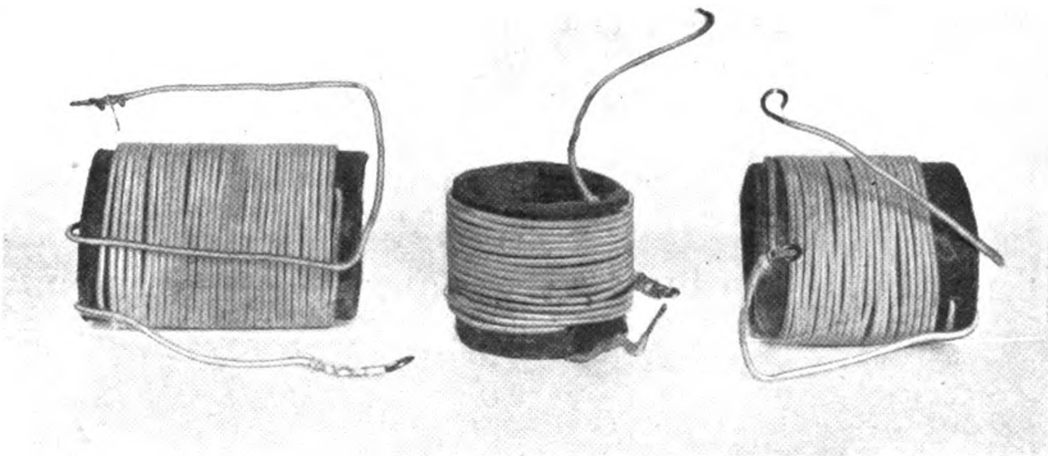


Fig. 5.—A near view of the modulator, reaction and oscillator coils, about half actual size.

The microphone is here used as a loosely coupled tune and detune absorption circuit. The valve is only gently oscillating in order that quite loose coupling may be sufficient to effect modulation, as tight coupling ruins the shape of the resonance curve. The plate current curve close to resonance is given in Fig. 4, and it can be seen that for the small fraction of a milliamp. required it is linear for quite a considerable distance. Either side of the resonance point can be used equally well, but not too near the peak (a silent spot),

as the characteristic is curved, for this particular adjustment, 1·5 to 1·7 ma. is about the best part to work on. In order to obtain selectivity the circuit was wired throughout with No. 16 D.C.C., and small spaced cylindrical coils of the same wire used, no dead ends or unused turns being allowed, and adjustment must be very smooth throughout.

It might be objected that the grid condenser rectification will introduce a lag, but this is essentially a radio lag, and at 100 metres even a 6,000-pp. note represents 500 radio cycles per audio period; this also applies to the lag introduced by the highly selective circuits, but as no appreciable reaction is applied to the microphone circuit, it has a very definite although somewhat small damping factor, otherwise it would not affect the plate current to such a large degree. In the writer's experience the radio lags introduced here only seem to amount to but a small part of the shortest audio period considered, although, if considered advisable, potentiometer rectification and somewhat less selective circuits can be used, but with a drop in sensitiveness.

The sensitiveness of this microphone is such that with phones in the plate circuit, and using only one valve, as Diagram 3, speech is quite clear at 10 feet from the microphone, although, of course, not loud, and quite strong at two or three feet, without using any kind of microphone trumpet. It thus compares quite favourably with the ordinary carbon microphone, while the quality is infinitely better, sibilants and explosive characters being practically as sharp as in the original speech.

The Conditions for Distortionless Low-Frequency Amplification.

By F. M. COLEBROOK, B.Sc., D.I.C.

(Of the National Physical Laboratory.)

Although many readers are no doubt perfectly familiar with the general and more obvious factors determining true reproduction, there are several more obscure points. These will be found fully considered below, and the following paper should prove of considerable value.

THE whole subject of distortion has recently come in for a great deal of attention. This is probably one of the consequences of the growing popularity of "broadcast" reception. It is quite understandable that once the initial condition of wonder has subsided the critical faculty will make its voice heard demanding an ever-increasing purity of reproduction, and it is desirable from every point of view that those in any way concerned with the design or production of apparatus intended for use in connection with the reception of wireless telephony in general and broadcasting in particular should realise the necessity of meeting this demand.

At a recent joint meeting of the Institution of Electrical Engineers and the London Physical Society on the subject of loud-speakers Capt. Eckersley, of the British Broadcasting Company, maintained that at present the weakest link in the transmission-reception chain is the loud-speaker. Making due allowance for the fact that his association with the transmission end of the chain will naturally dispose him to an indulgent view of this part of the process, there will probably be a very general assent to his proposition.

The unfortunate loud-speaker must not, however, be made the scapegoat to be loaded with all the sins of omission and commission of which the ear gradually becomes conscious

when "listening-in." In the demands it makes on the last valve of a receiving-set the loud-speaker may indeed be an indirect cause of distortion, for a reason considered at some length by the writer in a recent article in *The Electrician.** This, however, is the fault of the valve rather than the loud-speaker, and the trouble can be remedied by using a valve of suitably modified design for the operation of the loud-speaker. Such valves are, as a matter of fact, already on the market.

Quite apart from the loud-speaker, however, it is certain that low-frequency amplification is rich in possibilities of distortion. Without desiring to belittle in any way the very creditable performance of some of the low-frequency transformers at present on the market, the writer has good reason to state that many of them are very far from guiltless in this important matter.

The object of the present paper is not to specify any ideal design of transformer. That is a matter for experiment, and more experiment, and still more experiment! Its object is rather to consider the mechanism of low-frequency transformer amplification and to point out the essential requirements which must be fulfilled if it is to be free from distortion. The writer hopes that those actually engaged in experimental work on the subject may find herein some little assistance towards the practical solution of the problem.

It will be well to consider first exactly what is meant by distortionless amplification. Does this require that the wave forms of the input and output sound energy shall be identical? No; fortunately, it does not.

Given a certain fundamental and a set of associated harmonics the wave form can be varied very considerably by altering the phase relationships of the harmonics. It appears, however, that the ear is in no way disconcerted by such changes of phase relationship. It takes the total energy as it comes and receives from each harmonic the appropriate contribution to the total impression. The intelligent co-operation of the ear in this respect is very fortunate for low-frequency transformers since they are thereby freed from the necessity of maintaining unaltered the phase relationships of the constituent harmonics of the alternating currents passing through them.

An alteration of wave form, therefore, does not necessarily produce distortion. What must be kept unaltered, however, is the relative distribution of the total energy over the whole range of frequencies with which it is associated. Stated in electrical terms this means that the voltage amplification produced by a valve-transformer combination must be independent of frequency over the whole range of frequencies involved in the transmission of speech or music.

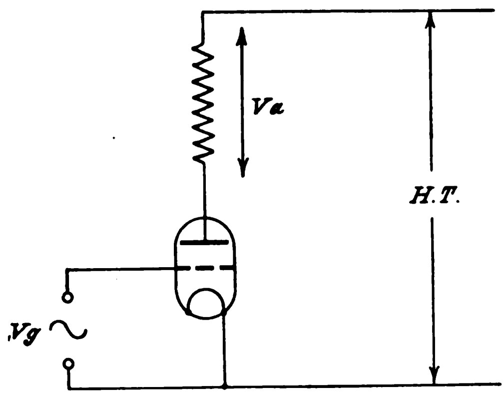


Fig. 1.—Potentials are produced across a resistance in the anode circuit.

To say that this distribution must be maintained unaltered is of course a counsel of perfection. Without doubt, a considerable deviation from this standard can be permitted in practice before a noticeable distortion is produced. The extent of this permissable deviation is not a matter in which it is possible to lay down any definite rule. It is probable, however, that a sound reproduction in which the distribution of intensity with frequency did not differ by more than 30 per cent. from the original for any given frequency would be accounted very good. Throughout this paper, therefore, this figure, corresponding to a 15 per cent. constancy of voltage amplification, will be taken as the standard to be aimed at.

In order to translate this into terms of amplifier design it will be necessary to consider briefly the mathematical representation of the amplification process. A

* "Grid-filament Conductivity: Its nature and effect on amplification." *The Electrician*, Nov. 23.

thorough treatment of the subject on mathematical lines would be out of place in a paper intended as much for the non-technical as for the technical reader. It is, moreover, unessential to the present purpose as the most important feature of the process can be made clear by a very much simplified analysis.

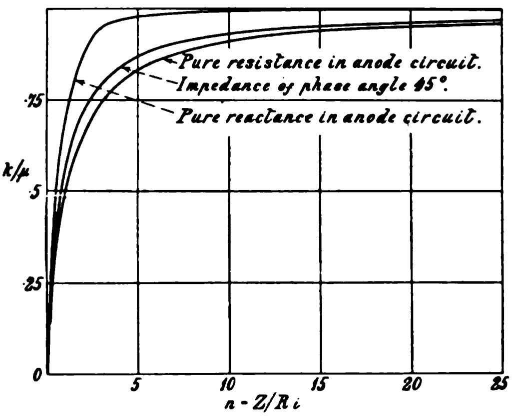


Fig. 2.—Showing relative amplification with a resistance, pure reactance and combined resistance and reactance.

Consider the arrangement shown in Fig. 1, which represents a valve, in the anode circuit of which is inserted a pure resistance R. If an alternating electromotive force of magnitude V_g be applied to the grid of the valve, then it can be shown that there will result across the terminals of the resistance R an alternating potential difference of magnitude V_a given by

$$V_a = \frac{\mu}{1 + \frac{R_i}{R}} V_g$$

where R and μ are constants dependent on the valve. These constants are usually referred to as the internal resistance of the valve and its voltage factor respectively, and their magnitudes are of the order 30-50,000 ohms for the first, and anything from 6 to 10 for the second.

Re-writing the expression in the form

$$\frac{V_a}{V_g} = k = \frac{R\ R_i}{1 + R/R_i} \mu$$

then k is the voltage amplification factor for the valve under the given conditions, since an applied grid voltage V_g produces a potential difference V_a, k times as large, across the terminals of the resistance R. It is clear that the important feature of the expression is not the absolute magnitude of R or of R_i, but the ratio of R to R_i. Calling this ratio n the expression for the voltage amplification factor takes the form

$$k = \frac{n}{n + 1} \mu$$

In the more general case in which, in place of the resistance R there is an impedance of magnitude $Z = nR$ and phase angle θ, it can be shown that the expression for k is

$$k = \frac{n}{\sqrt{(1 + n \cos \theta)^2 + n^2 \sin^2 \theta}} \mu$$

$$= \frac{n}{\sqrt{1 + 2n \cos \theta + n^2}} \mu.$$

The function $n/\sqrt{(1 + n \cos \theta)^2 + n^2 \sin^2 \theta}$ is illustrated in Fig. 2 for values of n from 0 to 20 and for $\theta = 0$, 45, and 90, *i.e.*, for the cases in which Z is a pure resistance, an impedance containing equal resistance and reactance, and a pure reactance. These curves demonstrate the great superiority of the reactance from the point of view of constancy of voltage amplification. For a variation of n from 3 to infinity the corresponding change of voltage amplification is only about 5 per cent., and for a variation from 2 to infinity only about 10 per cent. This is a fact of considerable practical value. It should further be noted that the larger the resistance component of the impedance the smaller is the permissible variation of n

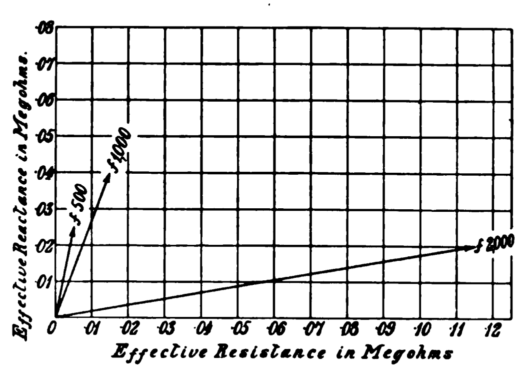


Fig. 3.—Primary impedances at various frequencies.

for a given maximum variation of voltage amplification.

We are now in a position to consider the application of the above results to the practical question of the design of low-frequency transformers for low-frequency amplification.

In the usual form of connection the primary winding can be regarded as an impedance inserted in the anode circuit. At a given frequency f this winding will have a certain effective impedance (its own impedance as modified by the presence of the secondary winding) and to this impedance there will correspond a certain voltage amplification factor defined as shown above. We will call this factor k_f. This means that an applied grid voltage V_g. of frequency f, will produce a potential difference $k_f\ V_g$ across the terminals of the primary winding. Across the terminals of the secondary winding the corresponding potential difference will be $k_f\ \rho_f\ V_g$, ρ_f being the value of the step-up ratio of transformation at the frequency f. As the suffix indicates, this is not constant with respect to frequency. The total voltage amplification produced by the valve-transformer combination is therefore $k_f\ \rho_f$ We may say, therefore, that if the transformer is to come up to the standard specified in this paper the quantity $k_f\ \rho_f$ must not vary by more than 15 per cent. over the whole range of the frequencies at which it is intended to operate. Strictly speaking, if the transformer is to be suitable for all kinds of speech and music this means the whole range of audible frequencies. Actually, if constancy to 15 per cent. is maintained down to about 300 cycles per second the result would probably be considered very satisfactory.

Before considering the possibility or otherwise of achieving this result it will be of interest to analyse the actual performance of a typical transformer, of average quality judged by present standards.

The measured effective impedances of the primary winding corresponding to three frequencies (500, 1,000, and 2,000) are shown in Fig. 3. The impedances are exhibited in vector form, with reactance as ordinate and resistance as abcissa. It should be noted that a frequency of 2,000 is in the neighbourhood of one of the resonance points of the system, for at this frequency the winding behaves almost as a high non-inductive resistance. (The possibility of such resonance points is of course attributable to the distributed self-capacities of the two windings and the capacity between the two windings. These self capacities play a large part in the performance of the transformer. It might be mentioned at this point that the measured effective impedance was found to depend to a very great extent on the way in which the terminals of the windings were arranged relative to each other and to points of fixed potential in the measurement circuit. The values given are for an arrangement corresponding as closely as possible to that of the usual valve circuit.)

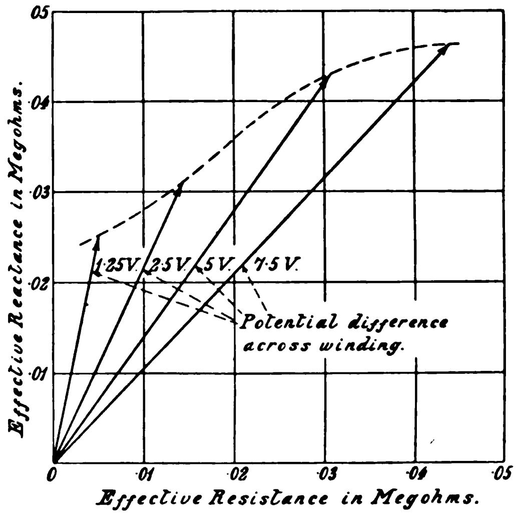


Fig. 4.—Showing variation of effective impedance with amplitude.

The diagram makes clear the very large variation of impedance which may be expected with frequency.

In general, variations of the magnitude of the effective impedance will occur not only with frequency but also with amplitude. This is illustrated in Fig. 4 for the primary winding of the same transformer for four different values of the potential difference across the terminals, at a constant frequency of 1,000. (The values of Fig. 3 are for a constant terminal potential difference of 2·5 volts.)

By reference to Fig. 2 we can see the significance of these variations of effective impedance. The curves indicate that, provided the effective anode impedance does

not fall below a certain definite amount dependent upon the degree of constancy desired, variations in its value will only cause relatively small variations in the corresponding value of kf. It is clear, however, that the transformer winding which forms the subject of these measurements does not satisfy this requirement. The consequence of this is shown in curve 1 of Fig. 5 which represents the variation of the calculated value of kf with frequency

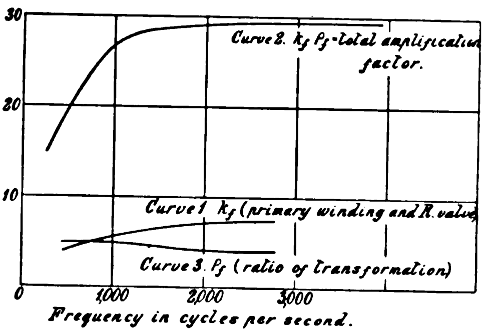


Fig. 5.—Variation of kf with frequency.

(assuming a value 10 for μ and 50,000 ohms for R_i.) Between the frequencies 500 and 3,000 there is a variation of just over 100 per cent. in kf. This variation is again reflected in curve 2 of the same figure, which shows the measured voltage amplification produced by this transformer in conjunction with an ordinary R valve. There is a very rapid falling off below a frequency of 1,000, and between 300 and 1,000 cycles/sec. there is a change of over 90 per cent. in the voltage amplification. From 1,000 upwards the change of total amplification produced by the valve and transformer is less than would have been anticipated from the corresponding change in kf. This shows that the change in kf has been partly compensated by a change in the reverse direction on the part of ρf, the transformation ratio. Curve 3 of Fig. 5 shows this apparent change in ρf, obtained by dividing the ordinates of curve 2 by those of curve 1.

This raises the question of the general nature and extent of the variation of the transformation ratio with frequency. It is not one on which the writer has very extensive information. It appears, however, that there is generally a tendency for the ratio to decrease as the frequency increases, and it is probable that many transformers at present on the market, with comparatively low primary impedances, owe their relatively good characteristics to a fortunate combination of an increasing kf with a decreasing ρf.

Coming now to the practical conclusions derivable from the above analysis, it is clear that there are two alternatives for the designer in his endeavour to maintain the constancy of the product kf ρf. Either he can arrange for the constancy of each factor separately, or, allowing either of the factors to vary, he can endeavour to compensate for the variation as closely as possible by producing an opposite variation of the other factor.

From a commercial point of view the first alternative would appear to be of doubtful practicability. It would mean that the primary impedance even at a frequency of, say, 300 cycles, must not be less than about 100,000 ohms, which would involve an inductance of the order of 50 henries in the primary winding and, of course, four or five times this amount in the secondary. Such a transformer, however well designed, would be of formidable bulk and probably no less formidable expense.

The second alternative would certainly seem to be the more hopeful. Even in this case, however, it is desirable to work for as large a value of kf as is practicable, in order to minimise the extent of the variation to be compensated for. In general this variation will be most pronounced in the region 300-1,000 cycles. What will be required therefore is a correspondingly rapid increase in ρf as the frequency decreases from 1,000 to 300. A preliminary investigation of the important factors in the variation of ρf would be necessary. It is probable that the study of the effect of varying the thickness of the iron laminations of the core (and also the material) would be a fruitful line of research, since the screening effect of the eddy currents in the core undoubtedly play a part in the variation of the transformation ratio.

There are, of course, other possibilities in the way of low-frequency amplification and, in the opinion of the writer, they should not lightly be disregarded. From a theoretical point of view the resistance-capacity type of coupling has a very great deal to

recommend it. The design of resistances whose value shall be independent of frequency is a very simple matter. (They should preferably be of wire, to avoid unsteadiness in operation.) As far as constancy of amplification is concerned such an arrangement is almost ideal. From a practical point of view, however, it has the serious disadvantages of requiring very high anode potentials and yielding relatively low amplification—not more than about 5 to 7 per valve (whereas a transformer coupling can be made to give as much as 30 per valve).

There is a further alternative which seems to the writer to present very great possibilities, namely, the reactance capacity coupling. This is of course identical in type of connection and principles of operation with the resistance capacity coupling and differs from it only in the use of a comparatively low resistance impedance in place of the usual anode resistance. It will be seen on reference to curve 3 of Fig. 2 that an impedance consisting of an inductance of not less than about 50 henries with a resistance of a few thousand ohms would give a minimum amplification factor of about $\cdot 9\mu$, with not more than a 10 per cent. variation with frequency from 300 cycles upwards. The amplification so produced is of course considerably less than the maximum obtainable with transformer coupling. In efficiency three such stages would be about equivalent to two transformer coupled stages, but it is more than likely that the small extra cost would be amply compensated by the greater uniformity and purity of reproduction.

Reverberation and Binaural Hearing in their Aspect to Studio Damping.

By E. K. SANDEMAN, B.Sc.

Reverberation.

WHEN a sound is produced in any enclosed space by means of any suitable source, such as a musical instrument or the human vocal organs, the wave front is propagated radially until it meets with some obstruction such as the walls of the enclosure.

On striking the walls it is reflected according to the ordinary laws of reflection, in greater or less degree, giving rise to a new series of wave fronts at each surface of reflection, which in their turn strike the walls of the enclosure and are again reflected. The sound is actually reflected backwards and forwards an infinite number of times, diminishing in intensity at each reflection until finally the volume of reflected energy is so small that the ear can no longer detect its presence. This process is correctly termed reverberation and is often incorrectly called resonance which has quite another meaning.

The amount of energy which is reflected at each impact depends entirely on the nature of the medium which is hindering the progress of the wave. Reflection of energy in any form occurs when the energy meets a surface of separation of two media of different characteristic impedance. The characteristic impedance of a medium may be defined as the relation between the maximum amplitude of stress and the maximum amplitude of strain, where the stress applied is of sinusoidal form.

In the practical case for sound energy we say for convenience that the sound reflected from a given substance depends on the absorption coefficient for the substance, reflection in air being understood. The absorption coefficient for a substance (designated by α) is the fraction of sound which is absorbed when a wave front strikes it. The reflection coefficient then $= 1 - \alpha$.

A large amount of work has been done in recent years on sound absorption in its aspect to reverberation, but since the subject is probably new to most people it will be simplest to take examples from the original work of Professor W. C. Sabine, of Harvard University, to whom practically all the credit

is due for placing this branch of science on sound lines of development.

In Sabine's original experiments his basic method consisted essentially in measuring by ear the time required for the reverberation due to a standard source of sound to reach the threshold of audibility (*i.e.*, to die away) after the source had ceased emitting.*

Starting with a bare room he brought in gradually increasing numbers of ordinary padded cushions and plotted the time of reverberation against the number of cushions. As the number of cushions increased he found, as might be expected, that the "time of reverberation" decreased. He found that the most effective method of damping was to have large areas of window open. He assumed, as seems to be very reasonable, that an open window represented 100 per cent. absorption and so was able to express the absorbing power of any material in terms of open-window units—an open-window unit being the absorbing power of 1 square metre of open window. If we express the absorption coefficient α of a substance per square metre of the substance, then on the assumption above, as we have already stated, the absorption coefficient represents the fraction of incident sound which is absorbed.

Some of the absorption constants obtained by Sabine and published in his original papers are given under.

ABSORBING POWER OF WALL SURFACES.	
Open Window	1·00
Wood sheathing (hard pine)	·061
Plaster on wood lath	·034
Plaster on wire lath...	·033
Glass, single thickness	·027
Plaster on Tile	·025
Brick set in Portland Cement	·025
ABSORBING POWER OF AN AUDIENCE.	
Audience per square meter...	0·96
Audience per person	0·44
Isolated woman	0·54
Isolated man	0·48
ABSORBING POWER OF SETTEES, CHAIRS AND CUSHIONS.	
Plain ash settees	0·039
„ „ „ per single seat	0·0077
„ „ chairs "bent wood"	0·0082
Upholstered settees per single seat	0·28
Chairs similar in style	0·30
Hair cushions per seat	0·21
Elastic-felt cushions per seat	0·20

In Fig. 1 is shown one of the original curves obtained by Sabine in his experiments in the Fogg Art Museum, relating the number of cushions brought into the room and the time of reverberation as defined above; cushions being the damping material then most immediately to hand.

It is evident from Fig. 1 that, by suitable damping, the "time of reverberation" of a room or chamber may be adjusted to any required degree.

This would have no practical value if it were not possible to relate the degree of damping to the requirements of musicians and their audience. Sabine made experiments with a committee of observers of musical accomplishment listening to a piano played in turn in five different rooms whose period of reverberation was adjusted until the acoustics as judged by ear were decided to give the best results.

The values of reverberation obtained are startling in their nearness to one another, showing that the exact degree of reverberation permissible is a very critical adjustment. They are so striking that they are given under:—

Rooms.	Reverberation time in Seconds.
1	0·95
2	1·10
3	1·10
4	1·09
5	1·16
Mean	1·08

Sabine remarks, "The final result obtained, that the reverberation in a music room in order to secure the best effect with a piano should be 1·08, or in round numbers 1·1 is in itself of considerable practical value; but the five determinations, by their mutual agreement, give a numerical measure to the accuracy of musical taste which is of great interest. Thus the maximum departure from the mean is 0·13 seconds, and the average departure is 0·05 seconds. Five is rather a small number of observations on which to apply the theory of probabilities; but, assuming that it justifies such reasoning, the probable error is 0·02 seconds—surprisingly small."

* With the limited means at his disposal it was very difficult to measure absolute value of sound intensity, it was possible however to measure relative intensity. He therefore employed as his initial sound a source such that the initial energy reaching the observer was one million times that at the threshold of audibility. The "time of reverberation" therefore represents the time required for the sound energy to decrease in intensity one million times. The actual sound generator was an organ pipe blown by air at constant pressure.

Binaural Hearing.

By binaural hearing we refer to the fact that the possession of two ears gives to the normal individual two pictures of a sound source which are simultaneously impressed on his mind.

This simple fact has many consequent results, some of which are so complicated that they have not been fully explained, while the physiological mechanism by means of which the two sound pictures are combined is very little understood.

A certain number of things have, however, been definitely established.

Just as the possession of two eyes has the advantage over one eye that stereoscopic vision is attained, so the possession of two ears has the advantage over one in that directive hearing is possible.

It is a fact that people who are deaf in one ear are able to locate a source of complex sound once they are familiarised with its nature, but it is not possible to locate by hearing a source of sound which is emitting a pure sinusoidal note when only one ear is available for observation.

The physical reasons underlying the location of complex sounds have been very fully discussed in an extremely interesting article by R. V. L. Hartley and Thornton C. Fry, Ph.D., in "Electrical Communication," Vol. 1, No. 4.

The authors point out that since we are conversant with three dimensions in our space the location of a source of sound requires at least three independent co-ordinates and that if more are obtained it is an advantage.

Normally in the case of a pure note we have :—

(*a*) The absolute intensity of the sound.
(*b*) The relative phase displacement at each ear.
(*c*) The relative intensity at each ear.
(*d*) The change in relative phase displacement at each ear on moving the head.
(*e*) The relative change in intensity at each ear on moving the head.

Of these (*a*) is of value only if the observer is familiar with the sound source, while (*c*) is possibly the one which might at first sight be expected to be of most importance, though there is evidence to show that (*b*) is of greater value in sound location, while (*d*) and (*e*) we must probably regard as being merely of effect in helping us to balance (*b*) and (*c*).

We have thus in the case of a pure note barely three co-ordinates by which to locate it.

In the case of a complex sound made up of two distinct notes we have double this number of co-ordinates, the corresponding accuracy of location being very much increased since it is possible to form combinations of co-ordinates giving separate data for location which may be checked one with another.

As sounds become more and more complex it is of course true that owing to the ear

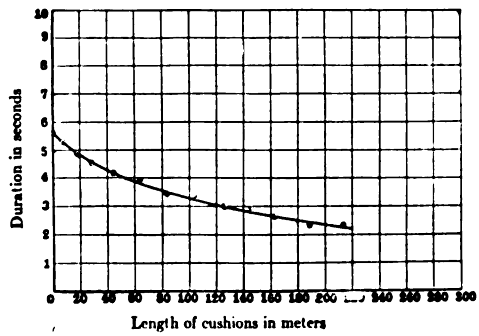


Fig. 1—Relation of reverberation to damping.

failing to differentiate clearly between all the notes or frequencies resulting, the degree of discrimination does not bear a simple relation to the complexity of the sound. This, however, is a small point which may be noted in passing.

When a sound source and an observer are placed in an enclosed space, such as a room, the ears make use of their binaural advantage to discriminate between direct and reflected sound.* For this reason any person of normal hearing will find that by going into a room having a fairly large period of reverberation (an ordinary plaster wall room devoid of carpets and furniture will do very well) the echo effects are found to become very much more troublesome if one ear is stopped up, and the loss in intelligibility of speech is out of all proportion to the loss of loudness effect. It is rather

* This is possibly because the discriminating mechanism of the mind, having located a certain set of sounds as originating at a source, makes allowances for their difference in phase, which allowance is not made for the echoes, which cannot be located to a source.

difficult to describe the special effect of monaural hearing in words, but since it is so easy for anyone interested to make the experiment in an empty room it is not worth taking up space here.

We have already pointed out the futility of trying to understand how the mind assesses all the data and forms an estimate of location instantaneously, and it will probably be simplest to look at it from the generalised point of view of the psychologist. The location of sounds by hearing is undoubtedly an instinctive process which may be inherited and which is probably modified and developed subconsciously by the experiences in the life of the individual. In other words, by continually observing the nature of the sound sensation produced by a sound in a certain position the record of the subconscious mind eventually enables the individual to assign a definite position to each type of sound impression.

In the case of hearing it is surprising how easily it is possible to assign a direction to a sound without any other knowledge of the method of location than that the noise "sounds" to be in such and such a direction.

The Application of the above Principles.

The Western Electric Company have recently taken out a patent for an improved method of adjusting the acoustics of a studio in order to obtain the best results for the reproduction of music. At a risk of repetition the patent is outlined below almost in its original words.

The patent covers broadly a studio in which sounds may be recorded or broadcasted with substantially all the natural effects that an auditor listening directly to the sounds would receive.

In order to achieve this result damping material is provided on the walls to such a degree that the time of reverberation will be between 0·5 seconds and 1·0 seconds as determined by Sabine's method referred to above. This method is described in "Collected Papers on Acoustics," by W. C. Sabine, Harvard University Press, 1922, as are also the experiments referred to above.

To obtain the best results the damping material should be so disposed on the walls of the studio that there are no large parallel reflecting surfaces opposite each other, and arranged so that the sound waves may not travel around the room and back to the pick-up device (*i.e.*, transmitter) without striking a damping surface.

It will be noticed that the time of reverberation specified has as an average a time very considerably less than that determined by Sabine as being best for an audience hearing music directly. The reasons for this are then explained in the patent as follows :—

Experiments have shown that owing to the time of reverberation in a studio, there is produced on the listener a different acoustic effect, depending on whether he hears the sound with both ears or indirectly through a single pick-up device as in the case of reproducing sounds from records or from broadcasting. Under the usual conditions of hearing reverberation is always present to some extent and for this reason the effect produced on a person in a room damped so that there is no perceptible reverberation is not natural.

When a person listens to music or speech in a room he naturally uses both ears and is thereby enabled by his binaural sense to discriminate between the direct source and the reflections which constitute reverberation. He thereby subconsciously minimises the blurring effect of the reverberation.

On the other hand, when a person listens to the same sounds through a single pick-up device he no longer hears them binaurally and hence loses this ability to discriminate between the source and the reverberations and the sounds reproduced are displeasing. Since the usual recording and broadcasting apparatus is not binaural it is therefore necessary to decrease the time of reverberation, that is, to damp each sound so that it will not "hang over" so long. If this is not done the reproduced sounds become unnatural and if the reverberation is much too large the sounds will be blurred. The more sensitive the pick-up device to the weaker sounds the greater must be the damping.

It has been found that by damping the walls of a studio so that the time of reverberation will be between ·5 of a second and 1·0 second, as determined by Prof. Sabine's method, records made in a studio so damped will give an effect which is as near true binaural hearing as it is possible to obtain without actual binaural hearing. To most listeners this appears as natural as binaural hearing.

Low Consumption Dull Emitter Valves.

By W. E. MILTON AYRES, A.M.I.E.E., Mem.A.I.E.E.

In the November issue of "Experimental Wireless" some details were given of a number of dull emitter valves. Since then several new types have made their appearance, and we describe them below.

IN the November issue of this journal were given particulars of a number of dull emitter valves then available. Since that date a new series of valves has been placed on the market by various manufacturers which require a very small filament current and enable primary batteries to be used economically.

These new valves are all of the thoriated tungsten type of filament. According to the writer's experience, they are not unduly fragile, but, of course, must be handled with care. Apart from mechanical strength, they also have this feature in common that they may be easily spoiled by ill usage. In this respect, however, they have a decided advantage over the coated filament type of valve inasmuch as they can usually be recovered.

It is desirable that users of these valves should have a physical conception of their action, and this is best given by an analogy. The filament consists of a solution of thorium, or thorium compounds, in tungsten. Just as diffusion takes place in a gaseous or liquid solution (as, for instance, sugar will diffuse itself through water until the whole is evenly

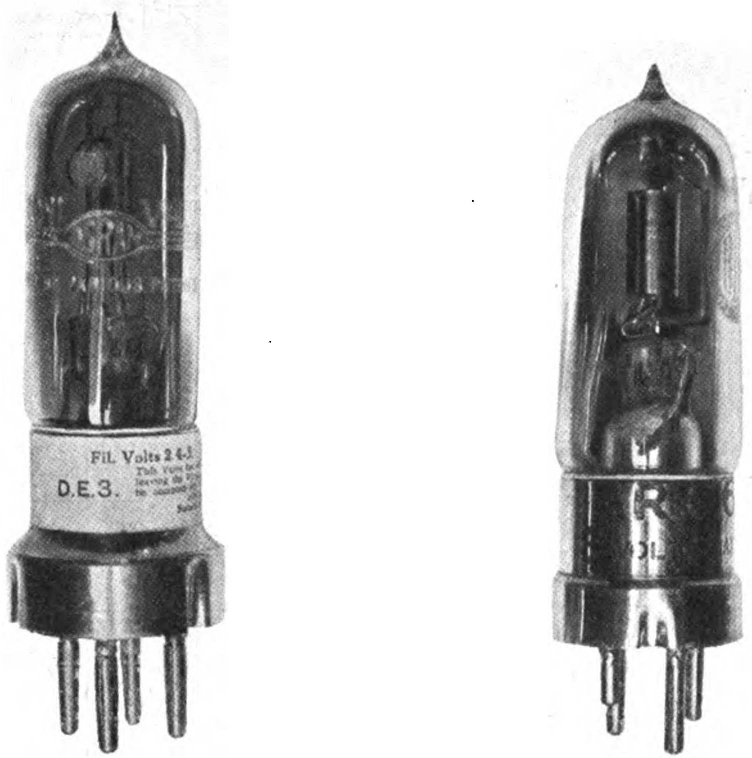


Fig. 1.—The "D.E.3" is a good general purpose valve, while the "AR.06" is an excellent H.F. amplifier and detector.

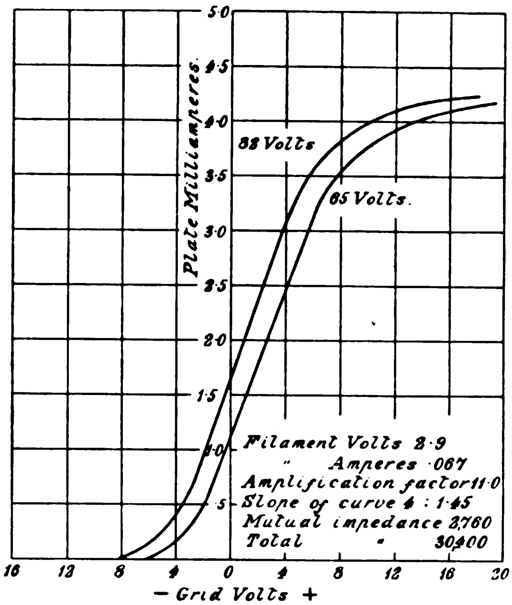


Fig. 3.—The Ediswan AR.06 has an amplification factor of 11 and a total impedance of over 30,000 ohms.

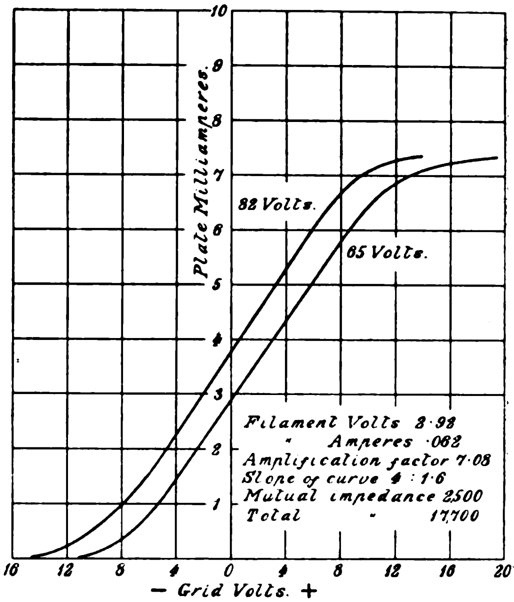


Fig. 3.—The General Electric Co. D.E.3 has a much lower impedance than the AR.06, but of course the amplification factor is only about 7.

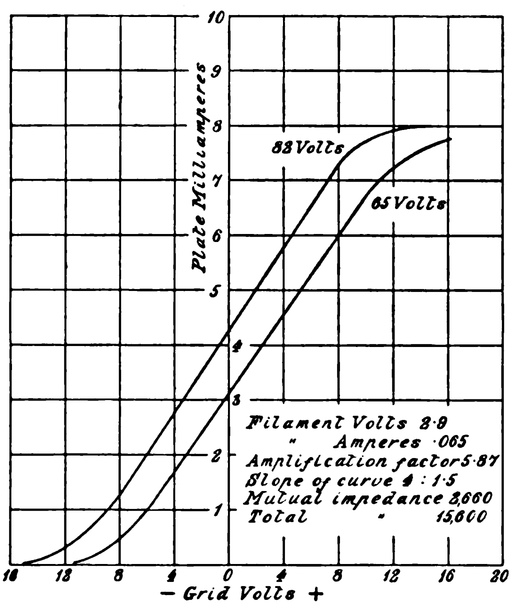


Fig. 4.—The French " Metal " is somewhat similar to the D.E.3 and AR. 06, the total impedance being a little lower while the mutual impedance is about 2,600 ohms.

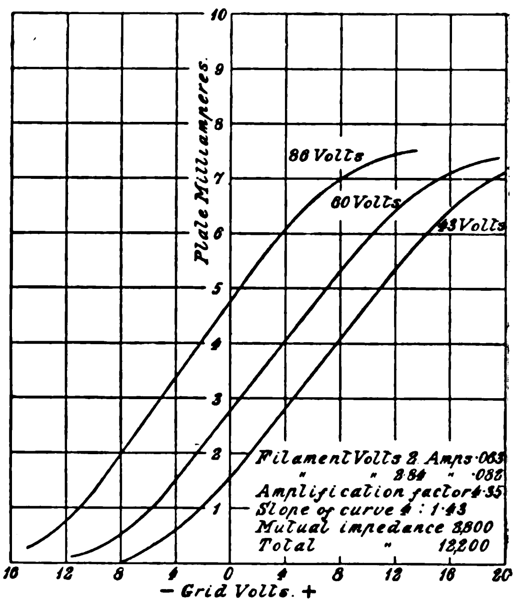


Fig. 5.—The Mullard D.F. ORA is slightly different from the three preceding valves in that it has a lower total impedance and a higher mutal impedance.

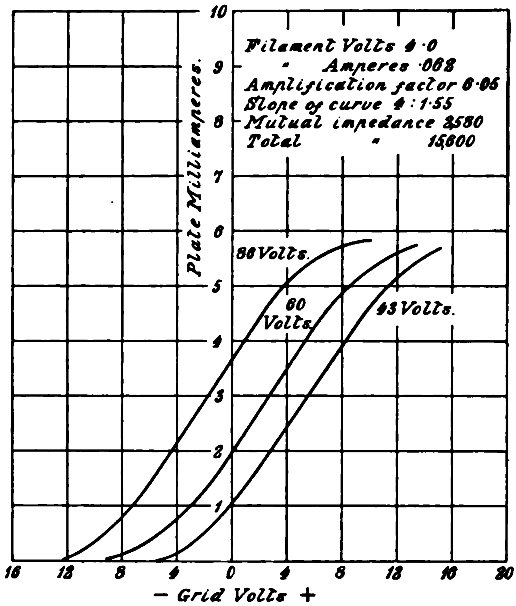


Fig. 6.—The B.T.H. B.5 is somewhat similar to the French Metal, but has a slightly greater amplification factor for a similar total impedance.

sweet), so one metal dissolved in another will diffuse itself throughout the mass, though usually only at an elevated temperature.

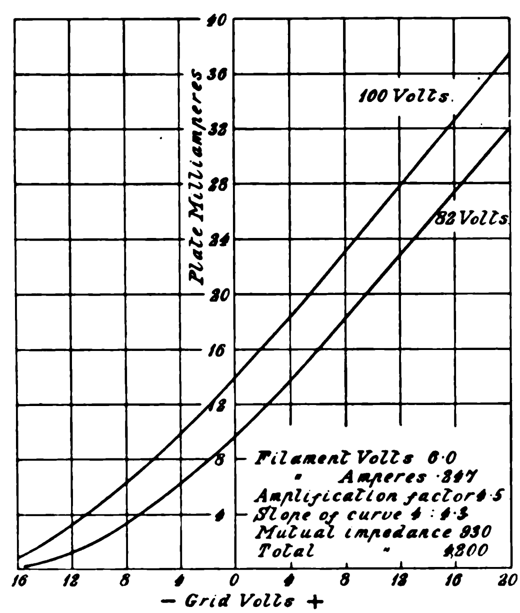


Fig. 7.—The B.T.H. B.4 with a μ of 4·5 and an impedance of 4,200 ohms is an excellent L.F. amplifier.

This process is used commercially in the case-hardening of steel, where carbon diffuses itself into the solid metal at a suitable temperature.

Thorium, as most readers will already know, is a radio-active substance, and breakes up into isotopes giving off " Beta " rays, or electrons, in the process. We have in the filament a solid mass permeated with this unstable radio-active substance, but

Fig. 8.—The B.4 consumes only 0·25 amp. Note the large flattened anode.

with a limited surface from which the electrons can be ejected. Suppose, for partial analogy, we imagine this as a long self-supporting column of water in which is dissolved an unstable salt, say, ammonium carbonate. The salt will diffuse through the liquid at a certain rate dependent upon the resistance offered to the migration of the free ions. This resistance decreases as temperature increases. There will be from the surface a certain evaporation of ammonia (NH_3) corresponding in our analogy to the emission

Fig. 9.—The construction of the B.5 is obscured by the magnesium getter.

of electrons. This rate of evaporation will depend upon the temperature, and can be considerably increased by warming, just as the electron emission is increased with increased brilliance (or temperature) of the filament. Now suppose this liquid column to be encased in a closed vessel and a vacuum pump applied. The evaporation of ammonia from the surface will be very much increased, and if suction is carried too far the evaporation might for a time be greater than the fresh supply by diffusion, and the "emission" of ammonia will fall in quantity. This is equivalent to applying a positive potential to the plate or grid of the valve, which has a suction effect on the negative electrons by electrical attraction. In this way the emission of a dull emitter valve may considerably fall in value by misuse.

The cure in either case is to keep up the accelerating influence in diffusion and stop the suction for a time; in other words, keep the filament alight, but disconnect the H.T.

From the above analogy readers will see the reason for manufacturers instructions not to exceed a specified filament current (*i.e.*, temperature) and plate voltage (*i.e.*, electron attraction). They might also add a warning about positive grid bias.

We would not like to frighten any readers, however, into thinking that any excessive care must be taken with these valves. It is too early to state life tests on the new ·06 ampere filaments, but the writer knows of an ARDE valve taking ·25 ampere which has done 11,800 hours' service, and the emission is still up to standard. One of the valves of which curves are produced in this article was delivered from the manufacturer's showing a total emission of only 1·10 milliampere, but two hours' "cooking" without any plate voltage brought it up to standard. Following this another was deliberately "spoiled," and recovered to prove the adaptability of the method. The procedure sometimes advocated of flashing for a very brief period

Fig. 10.—The D.F. ORA has inclined electrodes which distinguish it from the ordinary ORA.

with 50 volts is much too risky a performance for the amateur, and has no advantage except in time-saving. Emission recovery should be considered as an extreme measure and its necessity avoided by proper use.

The six curves produced show that a remarkably high standard has been reached in this class of valve, in fact, they are much superior in performance to any high-temperature valves yet marketed. The average amplification factor is high and the emission is ample for ordinary loud-speaker operation.

AR.06.—The high amplification factor and plate impedance make this an ideal valve for H.F. amplification, and it is also a good detector not too critical of plate voltage.

B.5, *D.E*.3, *and D.F. Ora.*—These are good general-purpose valves and have sufficient emission for L.F. amplification when used for an ordinary loud-speaker. When used as detectors it is essential to keep the plate voltage down, and any using these valves in existing receiving sets which have only one + H.T. terminal should alter them to bring out a separate wander plug for the detector plate voltage. With this precaution these valves are excellent rectifiers. When used as L.F. amplifiers negative grid bias will usually be necessary.

B.4.—This is a power amplifier of very modest watt consumption. Those who have only heard a loud speaker operated from a general-purpose valve have a revelation in store when they try this excellent product, both from the standpoint of volume and quality. The price is also moderate.

Metal.—This is a French product of very good quality, and included here for comparison with our British manufactures.

In using any of the above valves as detectors it is very desirable to use a variable grid leak of reliable make. In general they require a low-resistance leak, but the value is fairly critical.

All dull emitters are, unfortunately, somewhat microphonic, and this cannot be avoided as the filament is not run at sufficient temperature to destroy its vibrant elasticity. By sturdier construction and eliminating spring from the filament supports this fault has been much reduced recently, so that the present valves are no worse than many of the high-temperature valves in use.

The Scientific Preparation of Fusible Alloys.

By J. FREDERICK CORRIGAN, M.Sc., A.I.C.

It is well known that some crystals if set in a fusible alloy are liable to be damaged if the fusion point is too high. Details of suitable alloys are given below, and should prove of value to those engaged on accurate crystal determinations.

THE radio experimentalist may often have observed that many of the specimens of so-called "fusible metals" which are at present upon the market by no means melt at the temperatures at which they are supposed to do. Several samples of "Wood's metal" which the writer has come across have exhibited melting points above 90 degrees Centigrade, and hardly one which he has tested has shown the correct melting point of the alloy. These facts, of course, may be due to carelessness or accidents which have occurred during the process of manufacture, but nevertheless they restrict the sphere of usefulness of the supposed low temperature melting alloy, and place it merely on a par with an ordinary soft solder.

The preparation of fusible alloys for experimental purposes is a procedure which is not altogether devoid of scientific interest, and often it is advisable for the radio experimenter to prepare for himself the particular low temperature melting alloy which he requires for his special purpose. The preparation of the alloys merely requires care and accuracy in working, and if these important factors are borne in mind very satisfactory products will be obtained.

Generally speaking, fusible metals may be divided into two main classes, *viz.*, those which contain a certain proportion of the

metal cadmium, and those which contain bismuth in addition to cadmium and the rest of the necessary metallic ingredients of the mixture. The metal cadmium, when admixed with other metallic elements possesses the remarkable property of being able to lower the melting points of the other metals to an enormous extent, and for this reason alloys containing cadmium always possess very low melting points. Such alloys exhibit a considerable degree of ductility, and they can be rolled as well as worked with a hammer or other beating tools.

Bismuth alloys, on the other hand, whilst somewhat less expensive, are generally very brittle. Their melting points are not as low as those of the cadmium alloys, and they tarnish very rapidly when they are exposed to moist air. When they are immersed in hot water they become covered with a greyish-black film of oxide. These alloys are very useful for the purpose of taking castings of delicate objects. They expand to a slight extent on cooling, and thus a very clear and sharp-cut casting is obtained.

So much, then, for the general properties of the two classes of fusible alloys. Let us now proceed to a more detailed consideration of one or two of the more important and better-known examples of them.

Wood's Metal.

This substance is perhaps the best known of all the fusible alloys. As a reference to the table of cadmium alloys will show, Wood's metal consists of a mixture of 2 parts of cadmium, 2 of tin, 4 of lead, and 5 parts of bismuth. When carefully prepared it should possess a melting point of 158° F., and it should become very soft and plastic at several degrees below this temperature. The alloy is quite malleable and it has a metallic appearance not unlike platinum. The addition of 1-16th part by weight of mercury to Wood's metal lowers the melting point of the alloy to a considerable extent.

Lipowitz's Metal.

The above metal is another cadmium alloy whose composition is given in the above quoted table. The alloy becomes quite plastic at a temperature of 140° F., and at 158° F. it melts completely. It has a silvery lustre, and it can be polished and worked in almost any fashion. The alloy is very suitable for the purpose of soldering thin strips of lead and tin in those cases in which the use of ordinary solder would be inadmissable. On account of its silvery appearance Lipowitz's metal is very useful for soldering nickel.

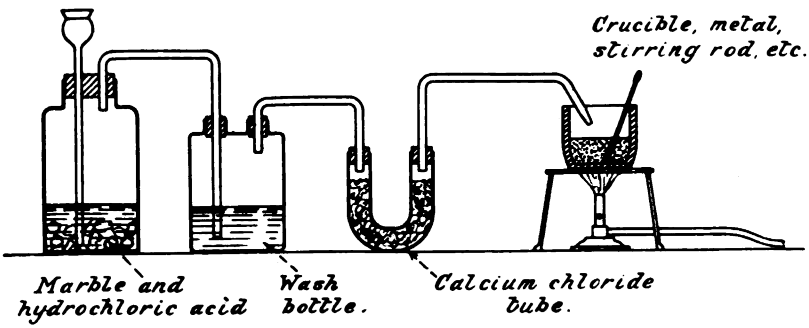


Fig. 1.—Suitable apparatus for the preparation of alloys.

Rose's and Newton's Alloys.

These alloys do not contain any cadmium, and consequently their melting points are higher than those possessed by metals which contain an admixture of the latter element. Their exact composition and melting points will be apparent from a glance at the table of bismuth alloys. These fusible metals find many uses in general scientific instrument making. Formerly, plugs of the alloys were inserted into the tops of steam boilers, it being supposed that they would melt at fixed temperatures. However, several disastrous explosions occurred with boilers in which the safety plugs had been fitted, and upon subsequent examination and enquiry it was discovered that under the prolonged influence of moist steam and high pressures, the composition of the alloys undergoes a complete change, and compounds possessing a much higher melting point are

formed. Consequently the use of these alloys for the construction of safety devices in boilers and other mechanical structures has been discontinued.

Method of Preparation of Fusible Alloys.

When a metal such as tin, cadmium, or lead is exposed to the atmosphere in a molten condition its surface rapidly becomes covered with a dull film of oxide. The non-realisation of this fact is one of the underlying causes of the failure of many amateurs to prepare fusible metals which really melt at their appointed temperatures, for a certain proportion of the metal is used up in forming the oxide, and thus the exact proportions which are required for the particular alloy are not maintained in the mixture.

Again, a fusible alloy must be entirely homogeneous in composition. That is to say, it must possess the same composition at all parts of its mass. It is very easy to throw the various metallic constituents of a fusible alloy into a heated crucible, and then to trust to luck and the guidance of Providence to do the rest. However, the constituents of the alloy have all different specific gravities,

Metal.	Melting Point (Degrees Fahr.)
Tin ...	437
Bismuth ...	520
Lead ...	620
Cadmium ...	609

Table Showing the Melting Points of the Constituent Metals of Fusible Alloys.

and they will form separate layers of molten metal if the contents of the crucible are not thoroughly stirred during the whole of the melting operation. Therefore when preparing fusible alloys the molten metal ought to be continually stirred with a thin stick of hard wood.

The question of the change in composition of the alloy which may result owing to oxidation whilst it is in a molten condition is another point which requires attention if the best results are to be obtained. Personally, the writer has, to a great extent, overcome this difficulty by allowing a jet of carbon dioxide (carbonic acid gas) to flow into the crucible during the whole of the proceedings. By this means air is almost entirely kept out of contact with the surface of the molten metal, and thus oxidation is prevented. The diagram (Fig. 1) will make the arrangement of the necessary apparatus clear. Carbon dioxide is generated in a large bottle by the action of hydrochloric acid (spirits of salts) on marble, chalk, or limestone. Before being allowed to flow into the crucible the carbon dioxide should preferably be freed from any acid

COMPOSITION.
(Parts by Weight.)

Melting Point.	Tin	Lead.	Cadmium.	Bismuth.	Name.
158° F.	2	4	2	5	Wood's Metal
158° F.	4	8	3	15	Lipowitz's Alloy.
167° F.	3	8	10	8	—
170° F.	3	11	2	16	—
204° F.	3	—	1	5	—
300° F.	4	2	2	—	Very Soft Solder.

Table Showing the Composition and Melting Points of Various Fusible Alloys Containing Cadmium.

COMPOSITION.
(Parts by Weight.)

Melting Point.	Lead	Tin.	Bismuth.	Name.
197° F. ...	3	2	5	Lichtenberg's Metal.
200° F. ...	1	1	2	Rose's Metal.
202° F. ...	5	3	8	Newton's Metal.
205° F. ...	6	2	8	—
211° F. ...	9	7	16	—
212° F. ...	3	4	8	—

Table Showing the Composition and Melting Points of Bismuth Alloys.

vapours which may accompany it by passing it through water, and with advantage it may also be dried by passage through a U-tube containing anhydrous calcium chloride.

In all cases the metals should be alloyed on their exact proportions by weight, the

metal which possesses the highest melting point being melted first. It is quite unnecessary to attain a very high temperature. Indeed, such a degree of heat is inadvisable, for it promotes the rapidity with which the metals will oxidise if the surrounding atmosphere is allowed to come into contact with them. The temperature of the crucible ought only to be slightly above that which is required to maintain in a thoroughly molten condition the metallic constituent which has the highest melting point.

Iron crucibles are quite suitable for the work described above, but unless the fusible alloys are made in considerable quantities at a time, a certain amount of waste is bound to occur. Crucibles made of graphite, such as are used by jewellers for the alloying of rare metals are cleaner and more efficient for the purpose in every way. Not only do they help to prevent the oxidation of the metal, but they possess the very great advantage of not allowing the alloy to cling and adhere to their sides when it is poured out. Thus, a good deal of wastage is obviated.

Of course, graphite crucibles are more expensive than those which are made of iron. They are also very brittle, and require much more care and attention than iron crucibles. Nevertheless, their employment for the purpose of preparing small quantities of metallic alloys is to be recommended.

From the foregoing description of the effective production of fusible alloys, it will be seen that the process is by no means a haphazard one. If fusible alloys which possess correct and accurate melting points are to be obtained their preparation must be very carefully carried out. The production of these alloys, however, is well worthy of attempting, for, besides the cementing of rectifying minerals and crystals in their cups, fusible metals find various other uses in radio and scientific experimental work, all of which, however, are rendered more or less inefficient if the alloy does not melt at its appointed temperature.

Ex-W.D. Oil-Immersed Smoothing Condensers.

MANY readers are, no doubt, familiar with the external appearance of Disposals Board 1 mfd. condensers contained in rectangular iron cans, with insulated terminals and a screw-plug for filling with oil. It often happens that these condensers may be picked up cheaply, but are found to be defective in some way. For instance, the condenser may not hold its charge, or the connections to the condenser elements may appear to have gone completely. This does not invariably mean that the condenser is useless, as the can actually contains four one-microfarad condensers, and the probability is that only one, or at the most two, of them are defective. These condensers are of the rolled type, but have a considerably higher dielectric strength than the ordinary " dry " " tinned " Mansbridge type, and will readily stand 600 volts if in good condition. It will be found that the condensers are arranged in two pairs of two in parallel, the two pairs being in series, thus giving a total effective capacity of 1 microfarad capable of standing 1,000 volts or so.

The interior of the condenser case is best got at by removing the top side (containing the screw-plug). This is soldered on, and may be removed by running a bunsen or blowlamp flame round the edge to melt the solder, the top being prised off at the same time by means of an old screwdriver or similar tool inserted in the joint. Before attempting this operation, however, it is necessary to empty out all oil as far as possible. On no account should the screw-plug be left in during the process, and it is advisable to confine the heating as far as possible to the edge to be unsoldered in order to reduce the vaporisation of any residual oil, and to avoid scorching the condensers inside. Once the top of the can is removed, the four condensers may be examined individually, and the defective ones isolated. Sometimes even the broken-down condensers are not altogether useless if the puncture is located in the outer layers, as in this case it is only necessary to unroll the condenser until the defective part is reached (usually indicated by a charred patch) and cut off the unrolled part.

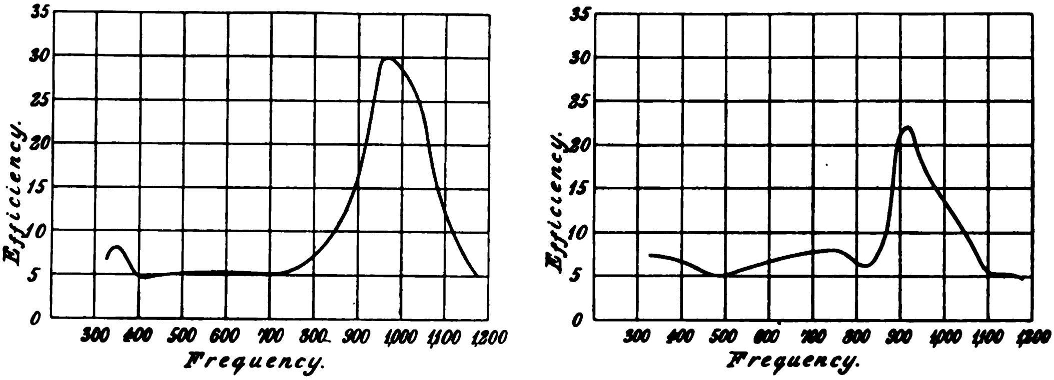
E. H. R.

The Damping of Diaphragms in Telephone Apparatus.

By C. M. R. BALBI, A.C.G.I., A.M.I.E.E.

It is interesting to note the recent change of attitude of the scientific world towards "resonance" in telephone apparatus.

In the early days it was the aim of manufacturers to design a "receiver" that had a greater degree of resonance than any of their competitors; after having done this they would erroneously claim that they had obtained the most efficient form of receiver on the market.



Figs. 1 and 2.—Two typical resonance curves of well-known makes of telephone receivers.

The reason for this can be readily understood when it is remembered the demand for a sensitive headphone was chiefly in connection with the reception of very weak signals in Morse telegraphy from wireless spark transmitting stations. In this case a chopped wave was arranged to give a musical note of about 1,000 cycles-sec. and sensitivity was only required at this frequency; but in present days when it is found messages can be sent so much more quickly and effectively by word of mouth a gain of efficiency obtained at the expense of resonance has become to be regarded with mistrust, as in this case it is essential that messages shall be as clear as possible.

Figures 1 and 2, which are representative of two well-known types of receiver, illustrate the degree that the mechanical resonance of a receiver diaphragm has on its efficiency.

The effect of resonance is threefold.

First.—The efficiency is raised at the resonant point.

Secondly.—The amplitude of a note at the resonant point is not proportional to the amplitude of other notes being reproduced.

Thirdly.—A note pitched at the resonant point is sustained.

The condition for perfect reproduction is that the efficiency of a receiver is constant at all frequencies as shown in Fig. 3.

The bad effect that resonance has on the quality of reception is obvious; it is sometimes difficult to understand how intelligibility is retained. Although it is known that after practice the ear becomes accustomed to the new conditions and treats the reception as if it were some new person speaking with a rather peculiar voice.

However, where the accurate reproduction of delicate sounds is required, like the notes of a violin solo on a loud speaker or in certain experiments where "Audiometric" measurements are being made, it is necessary to damp out resonance.

If such means as the placing of some soft substance, such as cotton wool, between the

diaphragm and the ear-cap is adopted the resultant damping not only reduces the tendency for the diaphragm to resonate,

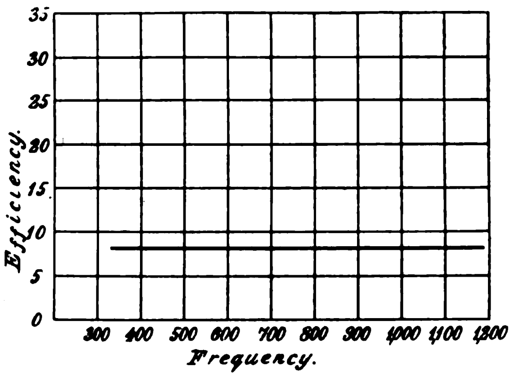


Fig. 3.—Form of desirable response curve.

but it also greatly reduces the effect of the forced vibrations, as can be seen from Fig. 4.

Other patent specifications covering different methods of applying mechanical friction to the diaphragm have this defect, but a system of electrical damping devised by Mr. J. T. Irwin has great advantages over the former methods.

Mr. Irwin has shown that by shunting the electrical system of an electro-magnetic receiver by means of a Capacity, Inductance and Resistance as shown in Fig. 5, the free vibrations of the mechanical system can be damped out.

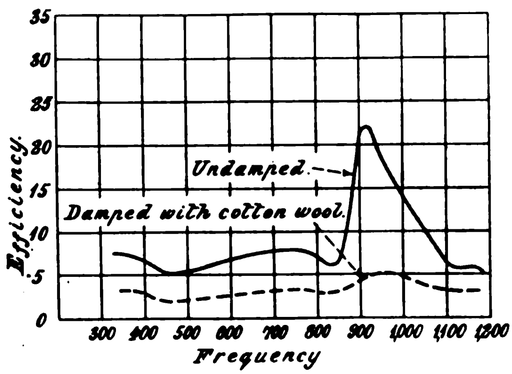


Fig. 4.—Showing effect of response by damping with cotton wool.

By suitably arranging the values of the apparatus in the shunt circuit, "Critical" or any required degree of damping may be obtained.

The first condition is that the capacity and the inductance when closed on themselves should be equal to the resonant period of the receiver diaphragm, this then fixes the product of the inductance and capacity.

Thus if L is the value of the inductance and C is the value of the capacity then $\frac{1}{LC} = w^2$, where w is 2π times the natural frequency of the diaphragm when undamped.

The second condition is that the relation $R_1 + R_2 = \frac{2}{Cw}$ has to be satisfied to make the electrical circuit dead beat, so that the deflection due to a current of a certain value when applied suddenly does not exceed that due to the same current when brought up to this value gradually, where R_1 is the

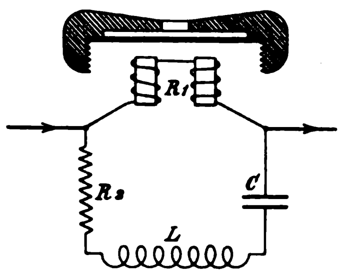


Fig. 5.—Arrangement of circuit to damp out free vibrations.

resistance of the receiver and R_2 is the total value of the resistance in the shunt circuit.

Lastly the ratio R_2 to $R_1 + R_2$ depends upon the ratio of the residual damping of the receiver itself including the damping set up by the action of the eddy currents in the diaphragm that would be required to make it dead beat without the resonant shunt, *i.e.*,

$$\frac{R_2}{R_1+R_2} = \frac{\text{Mechanical damping actual}}{\text{Mechanical damping to secure dead beat condition}}$$

These relations determine the values of the capacity, inductance and resistance to make the movements of the diaphragm dead beat for any applied current. The degree of damping required may be altered by varying the value of R_2.

The Neon Lamp as an Oscillation Generator.

By H. St. G. ANSON, F.P.S.L.

In the October, 1923, issue of "Experimental Wireless" considerable information was given on the use of Neon Lamps for wireless purposes. Below will be found an analysis of the conditions obtaining during the process of the production of oscillations and should be of considerable value to the advanced reader.

NUMEROUS articles have appeared in the technical press relating to the oscillations produced by neon lamps when connected in series with a resistance, and in parallel with a condenser. It is thought that it may be of interest to summarise a previous paper* which shows in what manner the frequency of the flashes may be calculated from the constants of the circuit.

Let us look at the fundamental circuit which is shown in Fig. 1. It will be understood that no current will flow until the voltage across the electrodes rises to a definite value—that is, the ignition voltage of the lamp—and therefore the resistance will be infinite for all values of voltage up to the value at which the discharge commences. When a condenser of capacity K farads is connected in series with a high resistance R, and a constant voltage V is applied to the ends of the circuit, the condenser will begin to acquire a charge, and the voltage v across its terminals will rise according to the law—

$$v = V\left(1 - e^{-\frac{t}{KR}}\right)$$

where t is the time in seconds after switching on the voltage. If the lamp is connected in parallel with a condenser, as in Fig. 1, it will flash on as soon as the voltage across the condenser reaches the ignition voltage. When this occurs the condenser becomes shunted with the low resistance of the glowing lamp, and consequently loses its charge. This continues until the voltage across it falls to the extinction voltage. If a and b represent the ignition and extinction voltages respectively, the glow will continue while the voltage falls from a to b. As soon as the glow ceases the condenser will charge up again from b to a, and so the process is carried on indefinitely. As we have already stated, the duration of the dark period is the time taken for the condenser to charge from b to a. Call this time T_1.

$$\text{Then } T_1 = K\,R \log (v-b)/(v-a)$$

In order to calculate the duration of the light period it is necessary to know the manner in which the resistance of the glowing lamp varies with the voltage across the electrodes. Fig. 2 shows a typical characteristic curve for a neon lamp, and from it

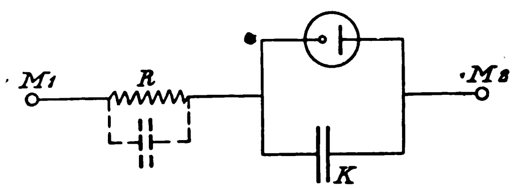


Fig. 1.—A circuit normally used for the production of oscillations.

we can deduce an expression for the resistance in terms of the voltage across the electrodes.

Put $\cot \theta = r^1 = (v - v_0)/c$
Now $c = v/r$

Where r = the effective resistance of the lamp,

$$\therefore\ r^1 = r\,(v - v_0)/v$$
$$r = vr^1/(v - v_0) \text{ ohms}$$

We are now in a position to find the duration of one light period. Let v = the voltage across the condenser at any time seconds after the commencement of the flash.

When $t = o$ $v = a$

Charging current flowing through R from the supply will be—

$$i_1 = (V - v)/R$$

where V = the constant applied voltage.

The current flowing through the lamp will be—

$$i_2 = v/r = (v - v_0)/r^1$$

The resultant current flowing from the

* *Proceedings. Physical Society of London*, Vol. xxxiv, Part v, 1922.

condenser, or the rate of discharge, will be—

$$\begin{aligned} \iota &= \iota_2 - \iota_1 \\ &= (v - v_0)/r^1 - (V - v)/R \\ &= v\ (1/R + 1/r^1) - (V/R + V_0/r^1) \end{aligned}$$

Also rate of discharge

$$\iota = -\frac{dq}{dt} = -K\frac{dV}{dT}$$

Hence $\frac{dv}{dt} + \frac{1}{K}(1/R - 1/r^1)v - \frac{1}{K}(V/R + V_0/r^1) = O$

The solution of which is:

$$v = \frac{Vr^1 + v_0R}{R + r} + Ae^{-\frac{R+r^1}{KRr^1}}$$

Where K is a constant which can be determined from the original conditions, when $t=0$, $v=a$.

Hence $A = \frac{Vr^1 + v_0R}{R + r^1}$

Therefore the voltage across the lamp

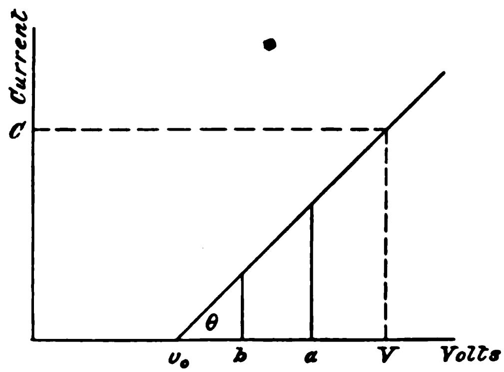


Fig. 2.—A typical characteristic curve for a Neon lamp.

at any time t after the commencement of the flash is given by—

Let $v = \frac{Vr^1 + v_0R}{R + r^1}\left(1 - e^{-\frac{R+r^1}{KRr^1}t}\right) + aE^{-\frac{R+r^1}{KRr^1}t}\ \frac{Vr^1 + V_0B}{R + r^1} = Q$

Then $v = Q + (a - Q)\,e^{-\frac{R+r^1}{KRr^1}t}$

When v falls to b—

$t = T_2 =$ duration of flash.

Therefore $b = Q + (a - Q)\,e^{-\frac{R+r^1}{KRr^1}q}$

Or $T_2 = \frac{KRr^1}{R + r^1}\log\frac{a - Q}{b - Q}$

Where $Q = \frac{Vr^1 + V_0R}{R + r^1}$

Hence the total time of a flash and a dark period is given by—

$$T = KR\left((\log\frac{V - b}{a - v} + \frac{r^1}{R + r^1}\log\frac{a - Q}{b - Q}\right)$$

It will be noticed that the first term is independent of the lamp characteristic, while the second is modified by the design of the lamp. This theoretical formula agrees quite closely with observed values of frequency when we are dealing with low frequencies, but diverges slightly at the higher values, indicating that, perhaps, we have overlooked some effect.

It may be of interest to just state that there are several other methods of producing oscillations by means of Neon lamps. Among the better ones are the following:—

Some lamps of the beehive type have the pressure so adjusted that on slightly reducing the voltage below the normal a pencil of positive rays will jump out from the wires of the cathode. If the lamp is put into a magnetic field oscillations will be produced. The frequency of these oscillations will depend on the slope of the characteristic curve of the lamp, the strength of the magnetic field, the value of the series resistance used, and the voltage applied to the ends of the circuit. Alterations of supply voltage will have the reverse effect on the frequency as in the previous case. Often the two types of oscillations may be simultaneously generated in the same tube. If the voltage is altered, the frequency of one will rise while the other will fall.

In some neon lamps oscillations may be produced even when there are no special connections or arrangements. This may be due to convection currents in the gas, which might cause a reduction of molecules in the vicinity of the electrodes. If a Neon lamp is run for a short time on a very high voltage the electrodes will become white hot and an arc will be formed. If tungsten electrodes are used this arc can be maintained at a very low voltage. If an inductance in series with a condenser is connected across the lamp when it is in this condition strong oscillations will be produced, owing to the negative resistance of the arc. Finally, I wish to offer my thanks to Mr. S. O. Pearson, B.Sc., for his great help with the mathematical portion of this paper.

A Source of Loss in High-Frequency Valve Circuits.

By CAPTAIN ST. CLAIR FINLAY, B.A., B.Sc., D.S.E.

Every experimenter is familiar with valve interelectrode capacity but possibly some do not realise its effect. This is discussed below and practical suggestions are offered.

If we consider any arrangement of a valve wherein the grid is directly connected to the filament by a resistance or leak, it becomes evident that a certain leakage of alternating currents must occur when such currents are applied to the grid circuit of the valve across such resistance or partial conductor as is usually the case, the aggregate leakage being due to component leakages of two kinds, *viz.* (*a*) conductive, along the resistance, and (*b*) capacitive, across the resistance—the amount of such leakages, individually and collectively, being dependant, other things being equal, upon (*a*) the conductance of the resistance, (*b*) the value of the capacity, and (*c*) the frequency of the alternations.

Examining first the conductive leakage (*a*), we find, firstly, that in the usual case where this is used across a condenser for the purpose of applying a negative bias to the grid of the valve or to discharge a condenser conveying potential variations thereto in

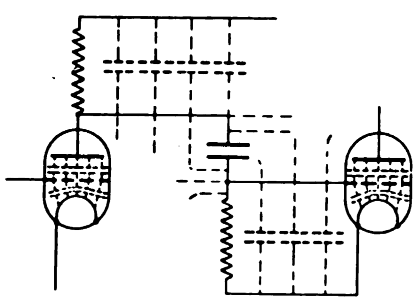


Fig. 1—Illustrating the capacatative losses in resistance coupling.

synchrony with such variations, such conductance will be very small and usually less than half the internal conductance of the valve itself, so that loss arising therefrom may in general be dismissed as negligible except in certain cases of transmitters where the conductance of the grid-leak may exceed half that of the valve.

A point also arises that the A.C. conductance of a leak varies inversely with the frequency, but as the order of conductance

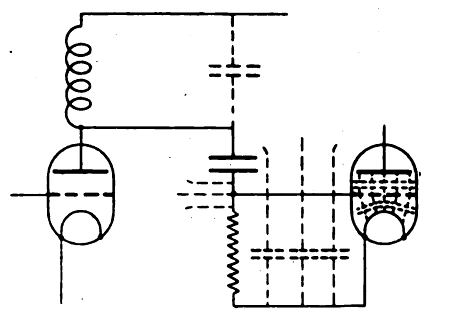


Fig. 2—A standard inter-valve coupling. Here the inherent capacity resonates the anode circuit, but still causes loss in the grid circuit.

is usually negligible, as stated above, it may in general be taken that such variation is also negligible in its influence upon loss.

Considering the second and third factors (*b*) and (*c*), however, we find from the formula

$R = \frac{1}{2\pi n C}$, where R=H.F. resistance or reactance of a capacity, C=capacity, and n=frequency, that the conductance or loss from this cause is directly proportional to both the capacity and the frequency, and from an examination of the representative valve and circuital characteristics in this connection we may deduce the order of loss arising from this cause in practice.

Taking an average example of a three-electrode valve suitable for high-frequency amplification, we find an internal inter-electrode capacity of the order of ·003-·005 milli-microfarads or ·000003-5 μF, and this at a frequency of 3,000,000 cycles, corresponding to λ 100, gives us a reactance or

internal impedance of the order of 15,000 ohms.

The internal resistance of such a valve will be of the order of 250,000 ohms, and in a resistance amplifier optimum amplification might be expected with an anode resistance

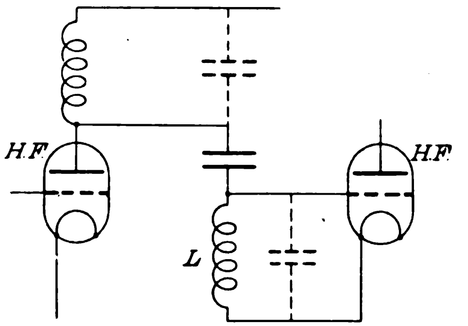


Fig. 3—A similar coupling to Fig. 2 but using inductance in the grid circuit. Both circuits are now resonant and capacatative losses are thus reduced.

of some ·5 meg-ohm, but across this resistance we have the internal valve capacity offering a H.F. path of R 15,000 ohms only, so that the effective resistance cannot exceed the latter figure.

Turning now to the circuital capacitance, we find that this, due to wiring, terminals, etc., will commonly be of the order of ·000005 to ·00002 μF in a well-designed receiver, and cannot in any circumstances be reduced much below the former figure, so that, assuming ·000006-8 μF in a reasonably favourable case, we find the shunt impedance at 3,000 kilo-cycles to be of the order of 7,000 ohms, which, considered conjunctively with that of the valve as determined above, gives a total shunt capacity across the anode resistance of some ·00001 μF with impedance of the order of 5,000 ohms only, and this will represent the *effective* resistance of the anode resistance at that frequency, no matter how much greater its actual ohmic resistance may be.

Now, since the voltage amplification obtainable will, other things being equal, depend in such an amplifier upon the ratio of external to internal effective resistance as shown by $A=\mu\times\dfrac{R}{Rp+R}$ where R = external effective resistance, Rp = internal effective resistance, and μ = amplification factor of the valve, and if we regard—as an analysis shows that we may in fact regard—the internal effective resistance as represented by the ohmic resistance and the capacitive reactance in parallel =15,000 ohms nearly, taking a practical average for $\mu=8$, then $A=8\times\dfrac{5{,}000}{15{,}000+5{,}000}$ =2·0, so that the loss amounts actually to 75 per cent. in the one (anode) circuit alone.

This is a prohibitive figure, and demonstrates the inefficiency of resistance coupling for H.F. amplification on short waves, a fact which is, of course, generally recognised.

But let us now consider the grid circuit of a valve under similar conditions. Here, common practice connects the grid to the filament conductively by means of a non-inductive resistance of a value between 5,000 ohms and 5 meg-ohms, the actual value in general considerably exceeding the internal grid-filament resistance of the valve, so that the conditions remain substantially as discussed above.

In these circumstances such an arrangement constitutes, in fact, a resistance coupling applied to the grid of the valve instead of the anode and the effect of capacitance

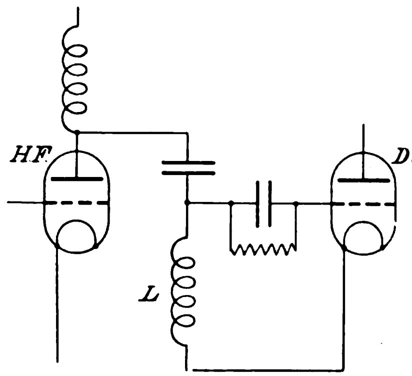


Fig. 4—A form of coupling combining the functions of resistance and inductance in Figs. 2 and 3, suitable for intervalve detector coupling.

across it will evidently be identical, *i.e.*, it will constitute a shunt path across the resistance causing losses which will be directly proportional to the frequency, so that at the high frequencies of the shorter waves such losses may, and actually will, reach such serious proportions as cannot reasonably be neglected.

Therefore, it is necessary in short-wave work to consider the grid circuit not less carefully than the anode circuit, and where a given form of coupling is unsuitable in the one case, it must logically be regarded as unsuitable in the other also.

In practice, inductance is used in the anode circuit in lieu of resistance for short waves for the reason that, if the values of inductance and capacity be suitably proportioned, the resultant *resonance* will produce a high value of impedance to a given oscillation frequency, and the inevitable capacity will thus become useful instead of merely a source of loss, tending to maintain voltage amplification by reasonance. Under

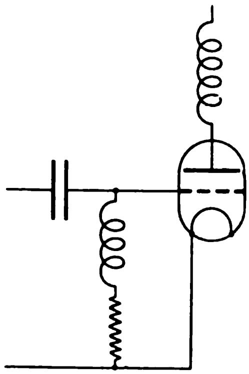


Fig. 5—Here the inductance and resistance are in series; a common arrangement in transmitters.

these conditions the circuit becomes an infinite-impedance loop or rejector circuit, the effective resistance of which will be $\frac{L}{CR}$, where L=inductance, C=capacity, and R=ohmic resistance of the circuit, so that if as before C=·00001 μF, and L=300 μH to tune to 3,000 kilo-cycles=λ 100, so long as R is small compared with the internal effective resistance of the valve as will usually be the case, the effective resistance of the circuit will be practically infinite compared with that of the valve and the resultant amplification almost equal to the μ factor of the valve, the loss being consequently very small. Actually, we can show by analysis that it should not in the general cases exceed 20 per cent., since R will always be almost negligibly small compared with the internal resistance, and R=effective resistance of the circuit, therefore nearly always more than twice that of the valve, under which conditions A must exceed 90 per cent. of μ, or, deducting minor losses, say, 80 per cent.

This is a very different matter from the preceding case where A=25 per cent. only, and if this is true of the anode circuit it is true of the grid circuit also—wherefore it is evident that inductance should be used in the grid circuit of a valve handling H.F.

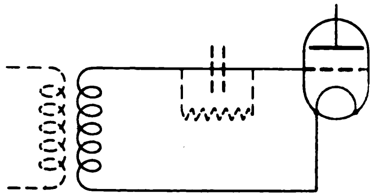


Fig. 6—In a single detector or transformer coupled stage the grid circuit normally forms an infinite impedance loop.

currents, and not resistance, in so far as the H.F. component is concerned.

Since, however, resistance may in practice be essential to a certain function of the grid connections, it becomes necessary to consider in what manner inductance may be arranged to supersede it in so far as the H.F. currents

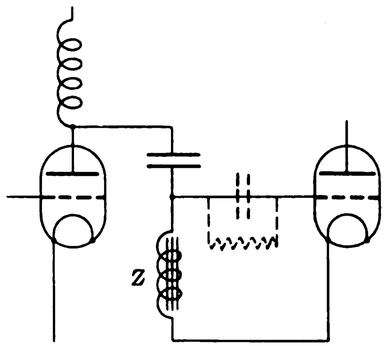


Fig. 7—An iron-cored choke is used here in place of L. A form of coupling particularly suitable for short waves.

are concerned without disturbance of such other functions.

In the case of a transmitter having a grid leak resistance of a few thousand ohms only the actual conductive loss along such leak may be considerable, and it is usual in such cases to place the inductance in *series* with the resistance to form a H.F. choke. Under such conditions we have inductance and resistance in parallel with a capacity, and the arrangement becomes a more or less highly damped rejector circuit according to

the value of the resistance, R being now usually considerable compared with the internal effective resistance of the valve, so that the impedance no longer approaches infinity, and the loss will consequently be greater than that of the same circuit without the resistance; but it will still be less than that across the resistance without the inductance, so that the latter may be said partially to serve its purpose—often to a highly important extent in practice.

But in the case (of a receiver) where the value of grid leak resistance will be comparatively high and usually more than twice that of the valve itself such an arrangement is not necessary, since the conductive loss may be regarded as negligible, and would in any case be ineffective since R would now be so large as to reduce the impedance of the circuit to little more than that due to its capacitance, which is the very effect we desire to avoid, so that here it is essential that the resistance be otherwise than in series with the inductance.

If we place it in parallel with the inductance the impedance of the circuit can be raised practically to that due to the inductance and capacity alone, since the conductance of the leak is in this case negligibly small, but this, on the other hand, may not suit the function of the resistance in the circuit.

A practical arrangement whereby the functions of both resistance and inductance may be fully preserved is shown in Fig. 4, and the impedance of the circuit can now be shown to be practically infinite and loss generally less than 20 per cent., as against the 75 per cent. of the standard arrangement of Fig. 2 at λ 100.

It will be observed that this condition actually exists in the usual arrangement of a single valve used as a detector and in transformer-coupled stages, in which the leak (if any) is connected directly across a condenser and the existence of a grid coil provides the inductance, the grid circuit in this case normally constituting an infinite-impedance loop; and this fact may be responsible for an impression that H.F. amplification is in itself inefficient on short waves, or that transformer coupling is actually more efficient than, for example, reactance capacity coupling, whereas if logically applied no such discrepancy exists.

We have assumed, of course, a condition of resonance, *i.e.*, that the grid circuit is actually *tuned*, and as this would manifestly increase the complexity of the apparatus and render it less convenient to operate it may be thought that the ordinary arrangement of simple leak must remain the more practical and therefore preferably be retained, notwithstanding its imperfection; but consideration of the matter will show that, whilst full efficiency certainly demands tuning of the grid circuit, an important measure of improvement will still be obtainable when that circuit is but roughly tuned or even semi-aperiodic, so that in a short-wave receiver, for example, a single coil—even untapped—can be designed to cover a band of say λ100-200 or 200-500 sufficiently well to offer considerably greater impedance than the usual non-inductive resistance, of whatever value, shunted by a natural capacity of the common order of ·00001-2 μF.

Further, the action of iron-cored chokes with high-frequency oscillating current may with advantage be considered in this connection.

It is evident from the formula $Z = \sqrt{(2\pi n)^2 L^2 + R^2}$ that the impedance of such a choke to oscillating currents is dependant not only upon the values of inductance and ohmic resistance of the winding, but increases particularly with the frequency, so that its effectiveness may be expected to approach a maximum on short waves, where it is particularly required, and, since the value of L can conveniently be made considerable, the impedance of the circuit can readily be made much greater than that of a circuit possessing only resistance and capacity; and since moreover no tuning will be necessary such improvement will be obtainable without complication whatsoever of the apparatus.

Analysis thus discloses that the standard circuital arrangement wherein a grid leak is connected directly between the grid and filament of a valve is very inefficient when applied to short-wave work, and it is suggested in these circumstances that the grid circuit should invariably be rearranged to form an infinite-impedance loop.

It will be appreciated that the apparent efficiency of the standard arrangement on short waves is in fact a spurious quantity due

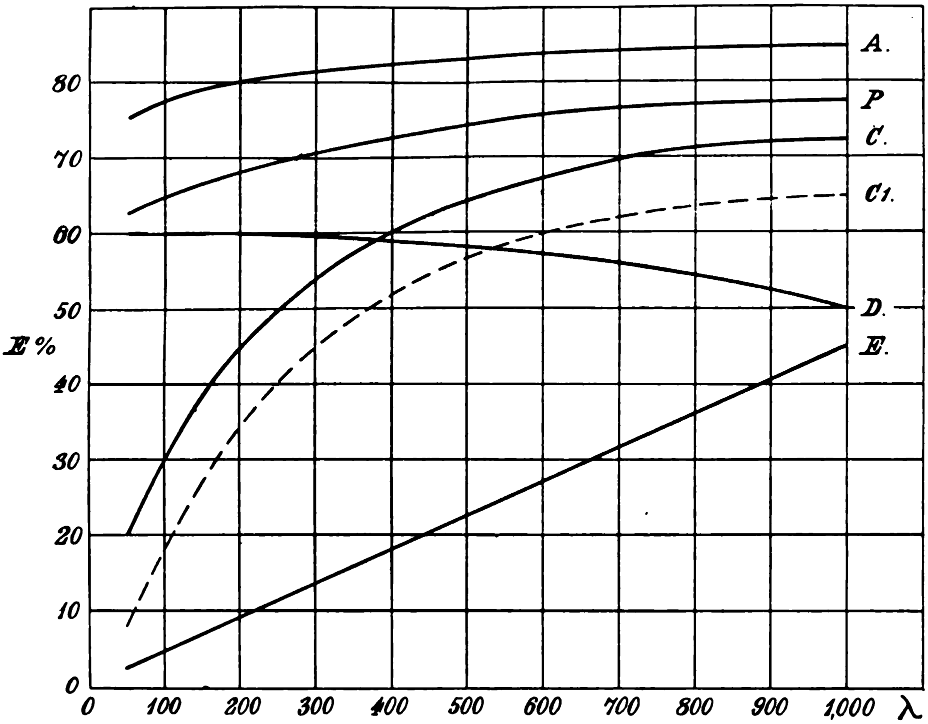


Fig. 8—Curve showing amplification at various frequencies for usual types of receiving valves.
A = Fully-tuned plate and grid.
B = Tuned plate, semi-tuned grid.
C = Tuned plate, grid resistance.
D = Tuned-plate grid choke.
E = Plate and grid resistance.

to the inherent reactive coupling between plate and grid of the valve and in the wiring, which at high frequencies becomes very considerable; and to this is due also the tendency to self-oscillation usually noticeable even when the circuital efficiency is as low as 20 per cent., a significant trait being the insensitivity of the arrangement *unless* operated close to the threshold of oscillation.

Increasing the circuital efficiency will, of course, have the effect of increasing the self-oscillation tendency and means require to be provided to control this; but since a single stage may now be more efficient than two stages coupled in the ordinary manner this should present no real difficulty in a well-designed apparatus, whilst the ease of operation may actually be improved, since one stage in every two may invariably be discarded so far as wave-lengths below λ200 are concerned.

A series of test curves showing the order ot percentage efficiency obtained in practice with the various forms of coupling enumerated when used in conjunction with valves of a type suitable for high-frequency amplification is appended, and clearly illustrates the practical import of the theoretical deductions contained in the article.

The Month's "DX."

GENERAL REPORT, By HUGH N. RYAN (5BV).

This month we commence "The Month's 'DX'" in its new form. As will be seen, there is a general report and discussion on the month's work, written by 5BV as before, and detailed district reports, each written by a well-known amateur in each district.

THE new form of our monthly notes will permit of them becoming rather more than a mere report. There is, each month, much to be discussed concerning "DX" work all over the world (and with our transmitters "reaching out" as they are now, world-wide "DX" is becoming a matter of interest to all of us). All the points of interest which arise will be discussed in the General Report, and the detailed local reports will deal with the work done in the areas which they respectively cover. It is hoped that there will be a keen rivalry between the various divisions to show the best report each month, as is the case in the States. Already two of the "Divisional Managers," 5KO for the West and 5JX for Scotland have seized upon this idea, and intend to keep their divisions "at the top."

5KO complains that there are so few active stations in the West that this Division will have more difficulty in doing good work than the others. I think that most of those who (like 5BV) have to work in a district crowded with transmitters would consider this an advantage! At any rate, if 5KO continues to do as well as he has in the past, his individual "scores" should keep his division well up.

This brings us to the question of the awful jamming which goes on in some places at present. When hearing it, one cannot but think that most of it is quite unnecessary. It is due to an extraordinary lack of co-operation between stations. So why not try to co-operate and avoid it? The telephony stations (and their name is legion) in London and other large towns could help immensely if they would curtail the interminable conversations about nothing in particular with which they at present occupy most of their time. They are the cause of most of the trouble.

Another group of offenders are the fairly powerful Morse stations who come on without any definite idea of what they intend to do, and call wildly every station they hear. We know that these calls spring from a genuine keeness for "DX," and the men concerned have the makings of really good "'DX' hams," but they must learn not to be selfish. Remember that every transmitter is a potential source of QRM, and before putting the key down one should consider "Is there any real object in calling this station?" If you have worked him often before and have no experiments to carry out with him, don't call him just for the fun of the working him again. Somebody else may want to work him, and even if this is not the case, your transmission may be jamming some other station who is doing good work.

Those stations which do not keep logs of all their transmissions should do so. You will find that, after keeping one for a few months, you become so interested in it that you do not like transmitting anything without entering it, and since this involves some trouble it has a wonderful effect in preventing you making those wild calls which, upon consideration, are not necessary, and certainly not worth the trouble of logging.

Altogether, the jamming should be considerably reduced if every station would realise that he and the man with whom he is working are not the only two who want to use the ether.

Having moralised at such length (and, I hope, to some effect) I will get on with the reporting side of the business.

My prophecy of last month about the transatlantic signals fading away was fortunately not fulfilled, and at present they seem stronger than ever. There was one rather bad week, but even then it was possible to "get across." It is certain that 2OD and 2KF will head the list of transatlantic successes this year, having worked over 40 Americans each. 5KO and 5BV have each decided to have the third place,

if possible. 5KO should get it, having worked 14 at the time of writing.

In Europe many new stations are in action, and new countries taking part in "DX" work. 1JW and LoAA are working in Luxembourg, both QSO England, as are Belgian P2, W2 and 4C2 (what curious calls some stations use!). 4AA, 4ZZ and 4GG are also in Belgium, but have not yet, as far as I know, worked England. XY (Geneva) is going strong, as is a new Swiss station, XZ. Both are QSA in London. A third Italian station (1ER, Milan) is now working. A new Dutch station, PCRR, sends on 100 metres. Danish 7EC is very strong and has worked several English stations. Dutch PA9 has now closed down. Its operator, Mr. Van Rijn, tells me that at the end they were using 1,600 watts, and there was "no more fun in working Americans, as everyone reported signals so QSA." Lucky man!

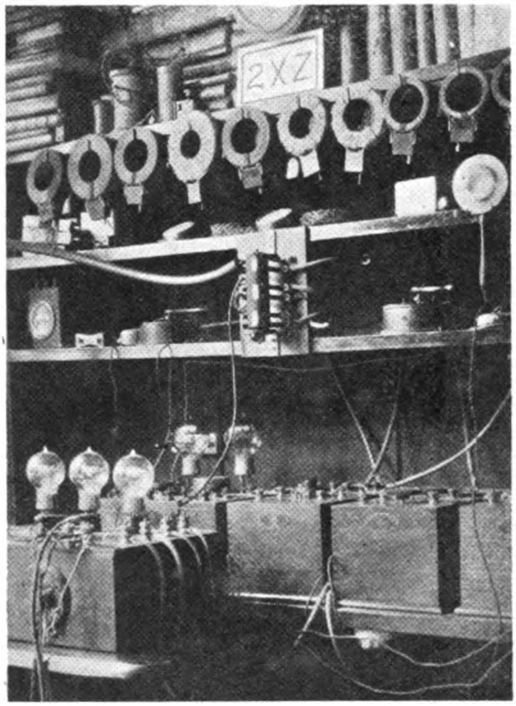
London District.

By 5BV.

No new stations have "got over" the Atlantic since last month, but several of the stations who had been successful previously have done more good work.

Our star station, in London proper, is, of course, 2KF. He has been heard nearly all over the States and Canada, and has at present over 100 American cards on his wall. 2OD, some twenty miles out of London, has done equally well. 2NM, 2SH, 2SZ, and 5BV have all worked ten or more Americans and Canadians. 2KF has been heard by 7ZU (Montana) near the Pacific Coast of America, and I believe 2NM has also been heard near the Pacific. 5NN, 5LF and 2WJ have done good work across the "Pond," while 2UV, a keen "DX" man who is handicapped by having no power mains available has "got over" on a hand generator.

I think that completes the list of Londoners who have been successful in transatlantic work. We have a number of other very good stations who could "get over" if they tried, but they don't seem to the "midnight oil" component of the work. 2ZT continues to do excellent European work, as does 2YQ, but neither have tried for America. Another of our best-known "brass-pounders," 2DF, of whom we all expected wonders in the tests, has completely subsided. He occasionally works stations in Scotland, and there is a fine "punch" behind his signals. He is unique among powerful London transmitters in that, even on full power, he confines his signals closely to one wave-length, and does not spread over about 20 metres each way- (those with guilty consciences please note!).



2XZ, owned by Mr. L. T. Dixon, who successfully transmitted a musical programme across the Atlantic on Dec. 28, 1923.

Apart from our "3 amp. in the aerial" stations, we have a number of very low-power stations who are doing splendidly. 5GF is one of these. During the last month he has worked XY (Geneva) with 0.18 amp. in the aerial and 0YR (Amsterdam) with 0.1. The latter test was carried out in bright sunlight, and signals were reported as R4 in Amsterdam. 2WY, 6LJ, and 6NF also do very good low-power work. These results remind me of the time when I could work Holland on a radiation of 0.01 amp. and make me wonder whether my 3 amps. is doing all it might!

I think the explanation lies in the fact that all this very low-power work is done on pure C.W., while most of the high-power

work is done on A.C.C.W. The only high-power pure C.W. stations in London are 2KF and 2NM, and the results obtained by these two show the value of pure C.W. (apart from the awful QRM caused by unsmoothed A.C.). In America certain cities like to boast that they are "spark-less" cities (which usually means that everybody uses raw A.C.). Why not go a step further and make London a "pure C.W. town"?

Finally, there are many tests in the near future. See that London stations show a good record. We are losing 2NM for a time, as he is going to see "how it's done" in America, so the rest of our stations must work a bit harder.

North-West District.

By "2KW."

BEFORE giving any particulars of "DX" work in the North-West District I should like to make an appeal to all experimenters situated in this area. It is of great importance that I be kept informed of any work done, regular reports being submitted. It might be suggested that these reports from the individual be sent to me by the 6th of each month. I shall then be able to incorporate any interesting items in my monthly report. Let us show the other districts that we are as keen and as eager to be to the fore in matters affecting the amateur "DX" man as they are themselves.

I cannot help thinking, how all those of us who are really "amateurs" in the true sense —"admirers" or "lovers" of the game—should be brought more into touch with one another. And it is with the transmitter that the greatest responsibility rests. He is the most important class of amateur in the country and therefore he should endeavour so far as he is able to co-operate and help his fellows. There is only one way, in my opinion, that we may achieve this most desirable end, and it is this: that in every city and district where there are sufficient numbers of amateur transmitters a society be formed. It can be an individual body; it may govern itself absolutely; it can, in short, do anything the members have a mind to do—but it must support any move made to render the position of the amateur easier by the R.S.G.B. There need be no definite affiliation even, but a trust in the one by the other and an honest desire by both to play the game. We in this country have many hundreds of amateur transmitters and I feel that until we *all* get together other countries will not show the confidence in us that we all desire so much.

By far the most important thing that has happened up to now in my district is the formation of the Manchester and District Radio Transmitters' Society. With a membership of upwards of fifty, every member holding a transmitting licence, this venture promises exceedingly well. It is the intention of the Society to co-operate in every possible way with other organisations, generally helping to advance the status of the amateur transmitter in this country. After reading my opening remarks it is to be hoped that other districts will follow our example. I am glad to see that Wolverhampton has already done so. The Society arranged two series of week-end range tests, the transmissions taking place from 0000-0100 and 2300-0000 GMT. on March 30 and April 6, 1924. Each station called MRTS and sent a five-letter code word. About fourteen stations participated. Reports on the reception of any of these stations would be very welcome.

With regard to "DX" working, G2JF and G6NI have received shoals of cards from U.S. stations. In October last 2JF succeeded in getting across. 2IJ on a power of three or so watts has been reported by 7ZM, also having worked many good distances. 2GW has been studying the most efficient method of maintaining his masts which, on occasion, reached 90 ft. in a vertical position. He has done some good "DX" reception and his name will be remembered in connection with observations on fading. 2PC has been waiting for rectifier valves all the winter and I regret to say he has not had the audacity to try a Chemy. Rec. However, he has obtained ranges of 1,000 miles with very moderate power.

My own "station" 2KW has, as usual, been "up for repairs" pretty frequently. Two 150-watt valves softened and after patient lingering (on my part) they were returned with due absence of gas again. A day or so later the elements got their say in the matter and wrecked my 70-ft. mast. Weep!!! In spite of all this my signals have been reported from the 1st, 2nd, 4th,

5th, 8th and 9th districts whilst WNP has also heard 2KW. Several stations, including 1KC, 1CMP, 1XAH, and 1AJA, have been worked. The last station, 1AJA, was worked on a power of 12·7 watts with an antenna current of ·4. The valve used was a Mullard 0/20 (20D hi !). Confirmation has not yet been received though the signals of 1AJA have often been heard at 2KW.

5IK has been experimenting with a method of obtaining H.T. which involved the use of that singular anomaly a chemical rectifier. Both 5IK and myself are convinced that no death could be too "lingering" for the wretched beasts. 2WK has sold up and bought, so we are told, a John Henry.

2TR, 2QJ (the guy who measures the amount of E.M.F. across two terminals by the distance he is thrown), 2PC (the expounder of the "bug key"), 5IK, 2UF, 2RM, 2RP, 6XY, and 5LG are all going strong though on low power.

One last word this month. Please let me have those reports by the 6th of each month and then we can make these notes highly illuminating to say the least of it. Best 73's.

Western District.

By 5KO.

THE report for the Western District is a somewhat difficult proposition, for the fact is that there are not many stations in this area, or at any rate very few, who show any interest in short wave "DX." During the brief intervals when there is no broadcasting a few stations may be heard on 440 metres turning out gramophone and piano music, but such business is outside the scope of these columns. Turning to 200 metres and below, perhaps we had better start with the Transatlantic work, as that is of chief interest to all "Hams." There are three stations in the West who are QSO America, and considering the small number in this locality who work on short waves this may be regarded as a very creditable percentage for the district. Thanks, however, to poor conditions during the last week or so, very little progress has been made. 5FS (Bristol) has been busy and has been unable to be on the air much, so his "bag" of Americans worked remains at two. 6RY (Bath) has worked three more—1XAH, and Canadian 1AR and 1DD, thus bringing his score up to five. 5KO (Bristol) has been very QRW with exams, and has only worked two fresh stations across the pond, 1BCR and Canadian 9BL, so his total now stands at 13. Hope it won't be unlucky. We were all on the verge of despair on account of bad "DX" conditions, but a great improvement has taken place during the last few days, and Sunday, April 6, was apparently a morning for super-"DX"; on this date 5KO was reported "all over the shack on two tubes" at 1XAR, and further surprised himself by working Canadian 9BL half an hour after daybreak. By the way, QST for March reports 5KO as heard by WNP at North Greenland.

The station at Kansas City, owned by a Mr. White, which received the prearranged test from 2XZ.

European "DX" does not progress much here; we are all QSO Denmark, France and Holland as usual. A message received *via* 6QB, London, states that 6RY and 5KO have been heard in Warsaw on a single valve super, and a frame. Some leg-pulling is suspected here somewhere. 5CC (Bath) is beginning to reach out, and has been heard in Stockholm. 5RQ (Bristol) had has a nervous breakdown and the doctor has forbidden "brass-pounding" for a few weeks. Hard luck, O.M. 2GV of Bristol is kept busy with his parish and cannot find time for much wireless work. 2CW is reported in Algiers, and 5KO in Italy. 5KM of Bristol is expected back on the air shortly; he has been off for a year, but has now

acquired some A.C. mains, and expects to create a big noise. No doubt the B.C.L.'s will welcome the appearance of yet another local station with a "hum." 2NS must be either dead or married, he seems to have dropped right out. Several Ford coil enthusiasts have appeared in the Bristol district, but it is hoped that they will soon see the error of their ways, as the local Radio Inspector has bought a receiver!

In conclusion, will stations in Devon and Cornwall (if there *are* any) please get in touch with 5KO if they want their activities chronicled. There must be some transmitters in this area outside the Bristol and Bath district. Let's hear them on the air, this section must not be beaten by London or the North. And where are all the transmitters in South Wales? Wake up, the West!

Scottish District.

By "5JX."

SCOTLAND does not boast many transmitters, there being only some half-dozen working "DX," but this in itself contributes to the excellent receiving conditions, distant signals not being jammed out by crowds of nearby QRM-ers.

Regarding general conditions, the most obvious is that signal strength varies directly with the distance! This anomalous fact is confirmed by everyone. Signals between stations in the North are never strikingly robust, unless huge power is used; for example, 2MG, reported all over the Continent, was weaker in Edinburgh during the R.S.G.B. tests than almost any other station heard. 2TF and 5JX QSA in Denmark, medium in Dollar, 24 miles away! Of the B.B.C. stations, not counting Glasgow, Bournemouth is easily the best received in Edinburgh; even Plymouth is not bad. Using the same receiver I get WGY several times stronger than 5NO, one-fortieth of the distance. This is of course quite satisfactory, as it prevents the nearer stations drowning out the distant ones.

One of the chief features of discussion here lately has been the relative merits of 100 metres and 200. The finding is roughly as follows:—100 metres—more QSA, less QRM, no harmonics from arcs, less QSS (though occasionally this is very bad, but is often nil), much worse QRN, when there is any about, bad night distortion of telephony, and much longer daylight range. The last-named is a good omen for summer work. The necessity for maintaining a steady wave is vital, a bad wave cuts down the range worse than low power.

Coming to actual results, the distinguishing feature this month has been tremendous Continental activity. Making an indiscriminate log here any evening French stations predominate every time, British being a bad second. Many new stations are reported by all listeners; Belgium's W2 seems the best of their contingent; P2 and 4ZZ also quite good. Danish 7EC seems the only representative heard much here lately. Italian ACD and 1MT seem to have largely retired in favour of a new man 1ER, who works nearly every night with G5SI and G5MO on all sorts of wave-lengths and a growling tonic train. Swiss XY was heard in daylight some time ago; he is quite a long way off. Of the innumerable Frenchmen now on 8DN, Lyon, can be heard QSA every night at 21.00, making calls in weird English to all sorts of people; 8AP is putting through some exceptionally strong telephony, and gives his call with a buzzer in front of the microphone. Other stations please copy! Luxembourg 1JW and Rhineland 8SSU are both reported here, and a great many new Dutchmen. A number of British telephony men are reported OK, 5QV and 2IM in daylight. Also 6VT, 2NM, 2KF, and 5DT.

Of the mystery stations that crop up from time to time 1CF heard on March 24, A42, in the early evening on 181 metres is rather a good one. G2XAA sounds a bit queer, too.

The local transmitters have been fairly quiet until just now; 2TF, 2MG, 6GY and 5JX have all been more or less out of operation for several months, and all have resumed, or are about to. 2MG is going strong with 1·8 amps. in his aerial, has worked Denmark, and is trying America. 5JX, after three months' silence, is now busy at all hours on 132 metres. He is also trying America, though with rather feeble hopes owing to modest equipment. A new arrival on the ether is Dingwall. Judging from his receptions this furthest-north British transmitter should do some good work. 5ST near Glasgow has been busy and has worked 2NM on speech with 0·5 amp.

Talking about America, the best time for working appears to be from an hour before to an hour after sunrise, on the shorter waves at any rate. After that there is a tendency to fade off. The last day or two of March QRN rendered all except the strongest signals useless, but on April 5 U's and C's came in too quickly to log; many of them A32, and 2OD was workig them with ease and precision well into the day. oAA has been trying to get across, but he did not appear to be QSL'd. A very notable result is that of Mr. J. G. W. Thompson, of Edinburgh, who besides a large array of European stations has logged six or more Americans on a single valve Armstrong with a 2-foot frame situated in a room in the worst screened part of the town.

In conclusion, there appears to be no doubt left that taken all round, the ± 100 metre wave does better work than the 200. Curiously enough the most pronounced advantage is its greater consistency. I fully believe that American "DX" will proceed throughout the summer. The only snag seems to be QRN, so it may be worth while now to produce the real atmospheric eliminator!

Radio Station 5CF.

By F. G. S. WISE.

THIS station is situated on Crouch End Hill, in the North of London. The antenna system consists of a four-wire 3-ft. diameter cage, 30 ft. in length, slung diagonally across the roof, directionally S.E.-N.W., and an earthed lead roofing, the shortness of the aerial being amply compensated by the fact that it is well above any local screening. A general view of the receiver and transmitter is shown in Fig. 1. Many experimenters who have visited this station have remarked upon its

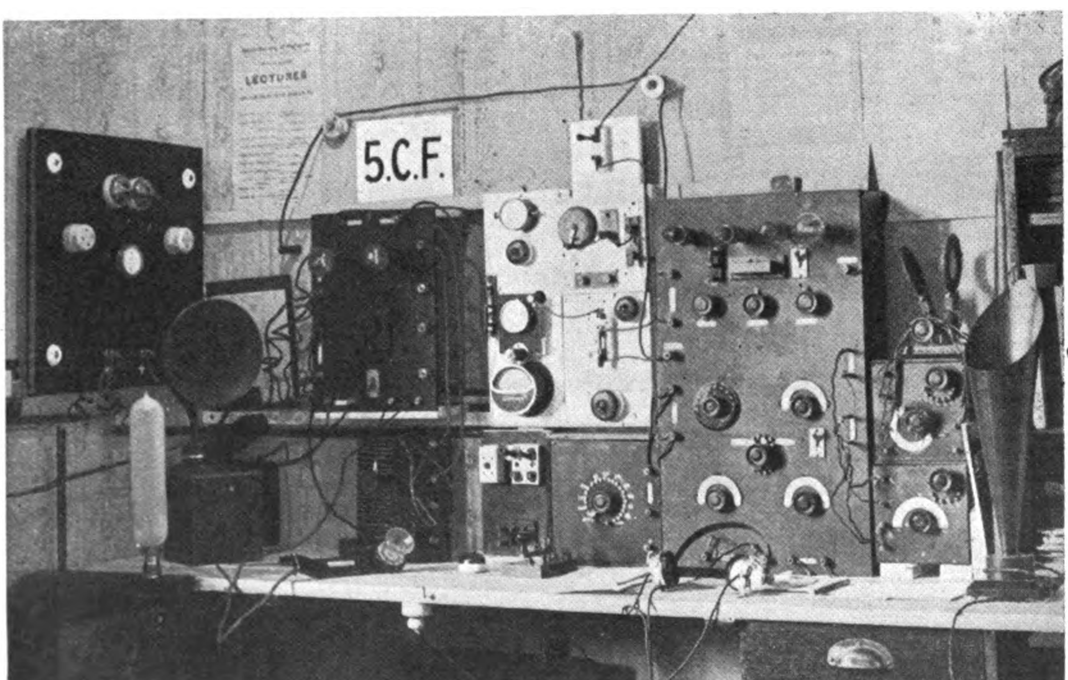


Fig. 1.—A general view of the standard transmitter and receiver.

neat appearance, but the author would state that the apparatus shown in the photographs forms only the permanent working units of the station, all experimental apparatus being assembled on a bench running at right angles to the one shown in the photograph. The author has found that by having apparatus in a consistent form it has proved of great value to stations giving reports

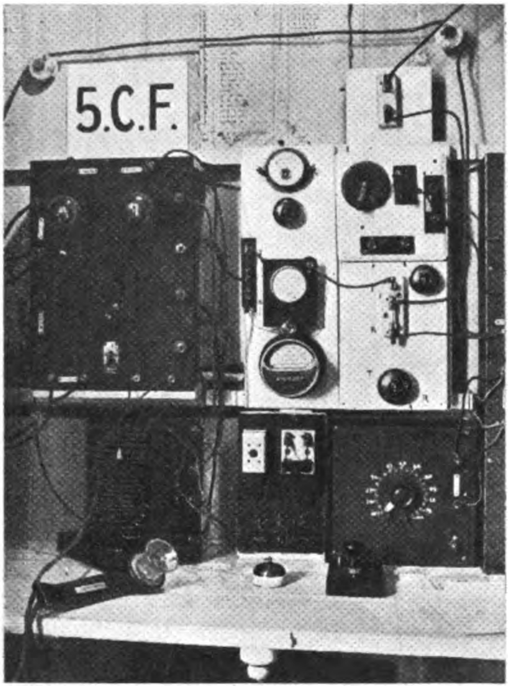


Fig. 2.—A close-up view of the transmitter.

on various experiments, as a standard transmission is always available for comparison. The same point applies when testing new receiving circuits, a receiver of a standard type being always at hand for comparison and calibration. Reception on new circuits can then be judged and their respective merits noted. A general description of the station may now be given. Looking from the left of Fig. 1 is seen the power supply board, which carried the arrival leads of the 240 D.C. mains, used for operating the transmitter. The resistance lamp is used in conjunction with a floating battery system for charging the filament accumulators. Fig. 2 gives a "close up" of the transmitter. The circuit is that of the standard reversed feed-back grid control, and using two valves in parallel. This circuit has been considerably stabilised by the use of a separate battery in the microphone circuit, and the author would suggest to the many experimenters who use this type of circuit, for low-power telephony, that their speech would be considerably improved if they paid more attention to controlling the voltage applied to their microphone. The helix is wound with heavy gauge wire, spaced, and is tapped to allow for fine wave-length adjustment (100–200 metres), the grid coil rotating inside. A switch is shown which throws the microphone or the key in circuit at will. The instrument board contains the filament voltmeter, the aerial ammeter (0–1 amps.), a ½-amp. lamp, and the plate milliammeter. A master rheostat gives control of the filament current, for either transmitter or receiver, power being controlled by a double-pole switch shown below the aerial change-over switch. H.T. supply for the receiver is derived from dry batteries, it being found that the enormous hum from the mains, if used, prevents perfect reception of weak signals. The receiver itself is the standard four-valve circuit, employing one H.F. tuned anode, detector and two L.F. As a point of note it should be mentioned that the anode of H.F. valve is tuned by a variometer, it having been found by exhaustive experiments that variometer tuning in the H.F. circuit on short waves gave the best results, although the hoped-for degree of amplification has not yet been obtained. Switches are provided for controlling the various valves in or out of circuit. The tuning apparatus on the extreme right of Fig. 1 consists of a tapped short-wave coil, and an acceptor circuit, consisting of a condenser and a tapped inductance, which is plugged in shunt with the aerial and earth. Switches are provided for the loud speakers. A switch for the use of an indoor aerial is also shown. As regards the efficiency of the station, possibly a high degree has not yet been reached, but on 10 watts input an average of ½ ampere aerial current is obtained. The greatest transmitting range on 'phone that has been reported was from Bolton, Lancs., about 200 miles. On the receiving side two to three valves are invariably used, and many distant stations have been logged, including American broadcast and amateur stations.

The Mechanics of Components.

By GEORGE GENTRY.

Home-made experimental equipment frequently suffers from faulty mechanical details. In the following notes an expert deals with the principles of good design and sound constructional methods as applied to wireless components.

No. 1.—Switch Construction.

THE forms of switch referred to in these notes are those of the multiple-contact type, which have long been used in all varieties of electrical apparatus. In the old galvanic batteries they were fitted under the title of current collector switches, or voltage collectors. Each stud of the switch was in contact with a cell, the cells being connected in series, and the operation of the arm over the studs collected one or any number of cells in series. When two arms were fitted, they became double-pole selector switches, and would take any cell, or any series of cells, from the battery, led to the terminals in either direction. Applied to accumulator batteries, they are still used as "accumulator" switches. The same form of switch is used on rheostats or variable resistances to collect sections of a resistance into series, and is used also in electrical engineering in this manner principally on motor starters or controllers.

In radio work the form of switch is applied as mentioned in the first place as a collector switch for high and low tension batteries, and in the second, as an inductance coil collector in the familiar form of the tapped inductance coil.

As far as possible, it is proposed to describe the correct method of assembling these switches, made up from the regular stock parts as supplied by wireless dealers, and as such they can as readily be set up and used as single way on and off switches, one stud being blind. There are two methods of fitting them, one with rotary spindle control, and the other with fixed spindle and arm control.

Fig. 1 is a section drawn to scale showing a single-pole rotary spindle multiple stud switch made up of a 1¾" length of 2B.A. screwed brass rod, running in a standard panel bush, also of brass. The whole of the fixing is done by No. 2B.A. brass lock-nuts with plain washers and a spring washer, the remainder of the switch comprising an arm, the requisite number of studs with washers and nuts, and a brass nut-bushed ebonite or compo knob. This is shown mounted on a ¼" ebonite panel. The standard throw or radius of the arms is apparently 1½" in all the specimens examined, and the usual diameter of the stud-heads 5-16". To set out, mark the spindle centre on the ebonite by means of a centre punch pressed in at first; and from this describe an arc of 1½" radius by sharp-pointed dividers, covering the number of studs required. The view to the left shows the end view of arm, which is 5-16" wide, and radiussed at both bottom corners. Allowing for the radii, the straight bearing portion of the arm will not be much over 3-16" wide, and, as the arm must rest with its flat on two adjacent studs at once to work smoothly, the studs must not have more than 5-32" gap between them. This makes the stud centres on the arc 15-32" apart, which may be less—say, down to 13-32"—but not much, because it will be seen that a 4B.A. nut and washer fills a greater space than the head, and the adjacent nuts will conflict on the underside of panel if the heads are put as closely as they might be. For smooth working, however, the closer the studs are together the better, so long as they do not touch, and in cases where a saving of room is necessary, it will be better to use studs of less shank diameter, say 5B.A.

When the panel is thus marked off, deepen the dots by means of the centre punch in conjunction with a light hammer. Put the panel on a flat surface over something solid, as a bench leg, and, holding the punch *upright* in the dot, one blow with a ¼ lb. hammer will suffice to give a good start for a drill, without splitting even ⅛" ebonite. The drilling should be done in the first place with a drill—preferably straight-fluted—much smaller than actually required. A 1-16" drill, for instance. Follow this on, so

far as the stud holes are concerned, with the correct size clearing drill. A suitable drilling machine is best, but if only a hand brace is available, it is important that it be held quite upright relatively to the panel. The stud holes are clearing holes, and not tapped. Before starting to drill the spindle bush hole, mark, by means of dividers, a ⅜" diameter circle on the ebonite concentric with the dot, and use this as a guide in the subsequent drilling. Drill this hole also at first with the small drill, and follow on, opening out the hole gradually by steps ; or, after drilling the small hole, use first a 3-16" drill, next a 5-16", and finally a ⅜" clearing drill, which may be as much as ⅜"+1-64" to

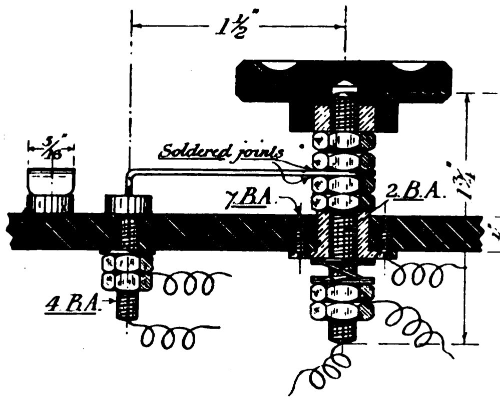


Fig. 1.—Illustrating the correct method of assembly of a switch, together with suitable dimensions.

clear the ⅜" outside diameter of bush. During the drilling, note whether there is any tendency to go out of centre of the circle, and if so, draw the eccentric hole over by filing the high side by means of a rat-tail file (*i.e.*, a small round file about ⅛" or 5-32" diameter and pointed). The subsequent accuracy of assembly of the switch and its truth of running depends upon all the holes being drilled truly square to the panel.

The bush is shown fitted the correct way to admit of making a joint for a fixed lead on underside of panel. If this is not necessary it can as well be fitted with the flange on the top side, but in either case fit the two No. 7 B.A. countersunk head screws to tapped holes in the ebonite. The flanges are ready holed for two screws on opposite sides, but it will be found necessary to slightly deepen the countersinks so that the heads of the size screws given stand either flush or a little under the face of flange when screwed home. The flange must sit truly on the ebonite to ensure that the axis is square all ways with the panel.

To assemble the switch spindle, it will be necessary to provide oneself with a pair of spanners for locking the nuts. Don't use adjusting spanners, or try to do the locking with any kind of pliers. A pair of suitable spanners can be made from finger strips of mild steel plate 1-16" thick, ⅝" wide, at one end, and tapering to about ⅜" wide at the other end, which may be rounded ; 4" long, or a little less will be a handy length. Cut a slot midway of the broad end, ⅜" deep and ⅜" wide, and adjust the width by filing the sides carefully to just slip on, a fairly easy fit, to the flats of a No. 2 B.A. nut, which measures about ⅜" across the flats in the generality of nuts examined. When finished, round off the corners at the broad end.

First provide six lock nuts, and tin two of them on one face. It is not necessary and will be a hindrance to leave the solder blob on the nuts, and the tinning must be wiped while hot. Also see that no solder gets to the screw threads. To wipe the tinned surface use a piece of clean waste or rag moistened with clean thin oil. This, if wiped across the tinned face when hot, will remove all the superfluous solder, and leave the equivalent of a bright tinplate surface. Tin both sides of the arm at the swivel end in the same way, but do not let the heat travel along the arm to avoid softening it. Wipe all the tinned surfaces quite free of oil and assemble as follows : Position the switch arm on the spindle, and lock it tightly between the two tinned lock nuts (tin to tin in all cases), after having fluxed all the faces a little. If the joint be then held in a blow flame, and the spanners applied carefully, the whole will form one nut a tight fit on the screw. Check this with one other lock nut (not tinned) on the underside, as shown, locked to the combination, and add the knob as indicated at the top in section. The latter is not screwed right home, but is checked with a lock-nut brought up to it on the underside. If the knob is not true enough for appearances, it probably may be made better by unlocking and shifting its position on the screw a little up or down, and re-locking. As shown, the frictional compression is obtained by the spring washer

on the underside. Put this between two plain washers, and adjust and lock the nuts at bottom to give just the right frictional resistance to the turning. There is only one other practical point to refer to, and that is that the underside of the lock-nut immediately above the bush should sit evenly on the bush. To make it do so is a simple lathe job, but, failing a lathe, it can be done in the following manner: Smear a little black paint (say a little gas black mixed with oil) evenly on the top rim of bush, and putting the spindle in position, without the underside nuts and washers, press home and turn it round backward and forward. If it is bearing hard at one point, it will show it by a black smear on the nut, but if bearing all round, the smear will take the form of a more or less bright ring on the nut. If a point shows, file it away carefully without touching the face elsewhere, and continue this till it shows up a ring when locked up in position. The lock-nut must be removed for filing, and put back in the same position.

The above constitutes all of a practical nature in making the switch, but there are one or two points to mention in the assembling. Put, say, the centre stud in first, and arrange the arm to normally spring down with its bearing face about 7-16" below the face of stud when the spindle is adjusted, with its nuts and washers on underside. Lift it on to the stud and see that it sits evenly just as drawn in the end view. If it tilts up at one end, twist the arm by means of a pair of flat-nose pliers till it bears evenly on the stud top all along its bottom edge.

The arm shown is about the simplest that can be fitted, made either of spring brass strip or similar German silver strip. Spring strip is harder and more springy than most sheet metal, and should not be made hot in the arm portion, or it will lose its springy nature. It should be No. 20 or 21 S.W.G. in thickness, 5-16" wide at point, and 7-16" wide at the swivel or rounded end, and plain clearance holed, not tapped.

The methods of lead attachment may be in the several ways shown. If the lead to studs is sweated on, sweat to the tinned point, and only one nut will be required, which must be tightened again after applying the heat, as this is sure to loosen it. The second nut is only applied as a binding nut when it is desired to make a screw joint. The latter can be effected by making a neat flat hook loop on the wire, which fits just round the screw. In the case of the spindle leads, such can only be fitted in the way just described if they are flexible. A rigid lead can only be sweated to the flange of bush as indicated, and sweat this to the flange surface and not to the screw head (as we are obliged to show it).

Fig. 2 is a similar scale part section of a swivel-spindle double-pole switch, made and fitted, so far as one arm is concerned, just as the foregoing. There is no lock-nut or tinned joint, however, on the upper side of the arm. The second pole is represented by a second

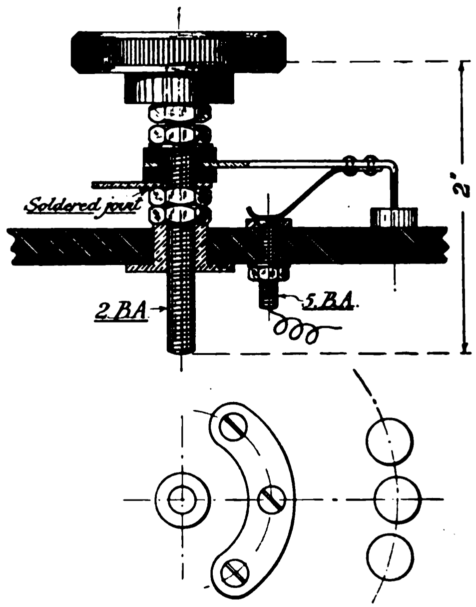


Fig. 2.—Design for a two-pole selector switch with a common shaft. Note the method of insulating the arms.

spring arm, which must be insulated from the spindle, and can be used at any angle to the first arm to suit the stud arrangement. If room will permit, it is much the best position to have it in opposition to the first arm, as then the switch is balanced, but it is possible to balance a single arm, as will be described later. The second arm is holed larger (not less than 9-32") and fits snugly on to an ebonite bush which is clearance holed to fit —a tight sliding fit—on the screw, and not tapped. It is tightened to the bush by a stout ebonite washer, also holed as the arm, and the whole joint is held down by the

upper lock-nut, which must have a washer under it.

The method of leading off from the second arm is indicated also in the plan below in Fig. 2. Over the range of studs to be in contact with the second arm is fitted a segmental strip of copper plate placed concentric with the spindle, and at about half (or less) the radius of the arm upon the top side of panel. This strip must lie flat, and should have at least one countersunk headed screw

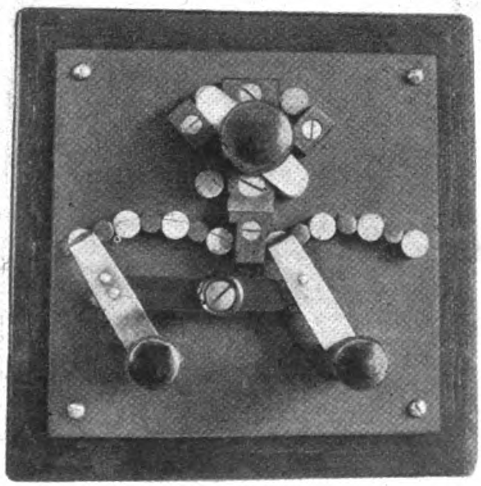


Fig. 3.—A double-pole battery collector switch with intermediate fibre riders.

at each end tapped to the ebonite, and one at or near the centre, passing through a clear hole, and nutted on the underside, as described before for the studs. It is important in this case that all the countersunk heads lie flush with the face of strip exactly. The lead off is a piece of spring German silver riveted to the arm as shown, bent down and formed with a flat-bottomed hook in the form of a shoe to ride nicely round the top face of segmental strip. The side bottom edges of this spring may be a little rounded at the shoe to aid in the sliding both ways, and the shoe must be fitted to bear nicely more or less all over the flat foot. Note that the spring must be of a much lighter gauge and more sensitive than the arm in order that its spring action will not prejudice the rubbing contact of the arm, and it is to avoid any trouble of this nature that the spring is attached to the point of the arm this way rather than the other way round. The lead is attached on the underside just as the studs, either by sweating or bound by a second nut.

There will be some more notes published dealing with points of construction in fixed spindle multiple-contact switches in a future issue, and in respect of these an example is given in Fig. 3, a photo of a fixed spindle double-pole battery collector switch, with a turn-button two-way series switch, with rotary spindle at the top. Details of construction will be forthcoming later, but a point to notice here is that the double-pole switch, having fixed spindles, is preferably made as a double switch with an ebonite bar link connecting the arms and keeping them at constant voltage. The link carries the controlling handle. Another point is that to prevent short circuiting adjacent cells by bridging over adjacent studs by the arm, the studs are spaced a little wide, and have between a fibre plug, which is raised slightly above the stud level, and thus acts as a rider for the arm, lifting it clear of the contacts. Other points to notice are that the riders of the turn button at top are also of fibre, and all the stops as well, the fibre in all cases being so fixed as not to connect any two contacts. The fixed spindles carry terminals top and bottom for both high and low tension battery connection, the terminals at the top are of insulating material, and are hooded to prevent accidental short circuiting. The whole switch is to be covered with a transparent insulator cover, which, however, is not celluloid for obvious reasons. This cover will have holes and slots, through which the knobs and insulated terminals project, and is designed to be foolproof.

The Trend of Invention.

Selective Receiving Apparatus.

British Patent Specification 212,177 (Marrec, Ltd.), describes a receiving apparatus intended to select and amplify Morse signals of constant wave-length to the exclusion of atmospherics and jamming signals. Audio-frequency beats are obtained by heterodyning, the beat-note being first amplified by an aperiodic transformer-coupled amplifier and then passed on to a cascade of three-electrode valves coupled by tuned transformers which are resonant to the beat frequency. The specification is lengthy and obscure—a defect which is by no means rare in wireless patents.

Another recently-patented selective device (British Patent 202,320, Marconi's W.T. Co., Ltd.), is illustrated in Fig. 1. O, P and Q are the usual H.F. amplifier, detector and L.F. amplifier respectively. By means of the centre-tapped coil E the valves H and J are differentially coupled to the output circuit D of the L.F. amplifier Q. One of the valves H is provided with a grid-condenser and leak MN, while the other valve J

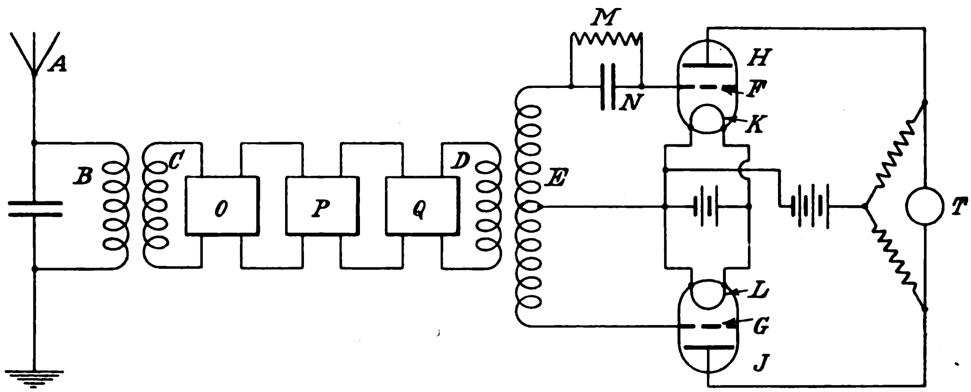


Fig. 1.—A selective system of reception.

latter cascade contains a greater number of valves than would be necessary for normal amplification as the filaments are dimmed to obtain a limiting action on loud parasitic impulses. In order to prevent self-oscillation in a system containing so many stages of amplification the inventor earths the positive H.T. terminal and not the filament battery; the H.F. side of the receiver is, of course, operated off separate batteries. Where the transmitting station uses marking and spacing waves provision may be made for selecting and recording both independently in order to minimise errors or loss of Morse characters due to strong atmospheric impulses.

It will be seen that the invention depends essentially on audio-frequency tuning and on the limiting action of thermionic valves, neither of which is in any sense novel, and it is not clear from the specification wherein the novelty lies. The wording of the speci-

has none. The anodes of the two valves are supplied from a common battery through two resistances, the recording instrument being connected at T as shown. The device is intended to act as follows:—A strong momentary parasitic impulse will affect both grids equally and oppositely, therefore the effects in T will cancel out. Sustained oscillations due to C.W. signals will, however, cause a negative potential to accumulate on the grid F of H while there will be no such effect in the valve J. Therefore the instrument T in the output will be affected by sustained oscillations. Unfortunately the circuit as shown in the specification and reproduced in Fig. 1 would not work, as a push-pull input circuit does not cause a cancelling effect in a push-pull output circuit but the effects add (*cf.* the ordinary push-pull audio-frequency amplifier). T is shown in what is virtually a differential or push-pull output circuit. If the anodes were

connected together and made to affect T in the same sense the device might work quite well.

The two schemes mentioned above serve only for the reception of Morse signals. The

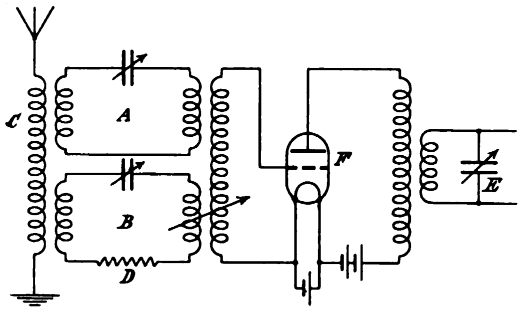


Fig. 2.—Another selective system.

system in Fig. 2 is the subject of a Telefunken patent (British Patent 206,838) and would answer equally well for the selective reception of Morse and telephony signals. The aerial circuit C is coupled to the receiver through the medium of two intermediate circuits A and B. A and B provide coupling in opposite senses so that they tend to neutralise each other's effect on the receiver; B, however, is highly damped by the series resistance D and is considerably detuned from the desired signal, while A is sharply resonant and only slightly detuned. Aperiodic impulses or received oscillations well off tune will tend to cancel, while oscillations of the desired frequency will affect A so strongly in comparison with B that their effect will be substantially passed on to the receiver. A

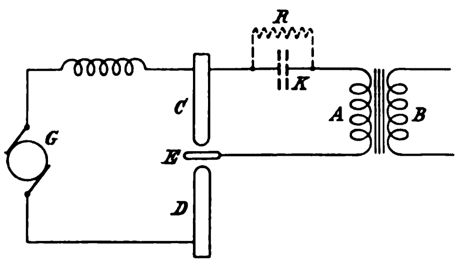


Fig. 3.—A controlled arc.

very similar scheme was recently patented by Round (see Exp. W., Vol. I, No. 1).

Talking Arc with Control Electrode.

The fact that an arc can be made to act as a telephone receiver was discovered by Simon some thirty or forty years ago, but it is very insensitive compared with other forms of receiver. The Telefunken Co. have recently patented the use of a control electrode between the carbons which they claim renders the device more sensitive (British Patent 203,293). Fig. 3 shows the connections. The arc electrodes C and D are supplied from the source G through a suitable choke. The control electrode E takes the form of a ring. When it is desired to control the bias on E a condenser may be inserted at K and shunted with a resistance R. It is desirable to provide means for cooling the ring E. It is stated that the device will act either as a receiver or conversely as a microphone transmitter, A B being the input or output transformer as the case may be.

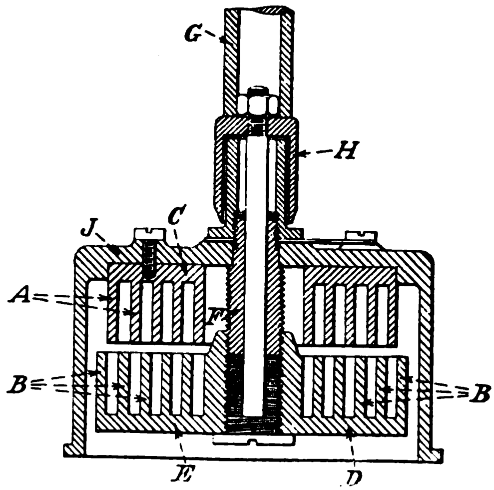


Fig. 4.—Rigid condenser construction.

Variable Condenser.

A large variety of variable condensers have been patented recently and the construction depicted in Fig. 4 is a distinct departure from the usual types (British Patent 212,199, A. Courtecuisse). The figure is practically self-explanatory. A and B are two sets of concentric annular cylindrical surfaces capable of interleaving to a variable extent without touching. The upper set A are connected together and fixed to the case J. The lower set are carried on a vertical rotatable threaded shaft F.

Direction Finding.

At the meeting of the Wireless Section of the Institution of Electrical Engineers on March 5, there was an interesting discussion, which showed that "direction finding" for navigational purposes is making progress. The paper set down for reading, entitled "Development of the Bellini-Tosi system of Direction Finding in the British Mercantile Marine" was not actually read, the author, Commander J. A. Slee, C.B.E., R.N. (retired) stating that since preparing it he had obtained additional new information, and with the permission of the meeting he would proceed with it, and asked that his paper, as set down, should be taken as read. But he remarked that the term "Capacity error," which he had used in section marked *f* was not a good term; the errors were not really due to capacity, they might be termed rather as errors due to working of the instruments. And with regard to the table, "Record Working of Ships' Direction-Finders," sixty-nine reports have now come to hand. They show results which come within the limits given in the body of the paper. A considerable number of speakers took part in the discussion, their remarks indicating some of the difficulties obtaining in "direction finding" for marine navigation. There was a difference of opinion as to whether the spark system or the continuous wave system was preferable for transmission of signals. Other remarks dealt with possible error due to variation in the loading of the ship and consequent difference in height of the instruments above water line, influence of waves deflected from the sky (that is the newly assumed envelope of frozen nitrogen); apparently fog does not introduce errors. The topic of sending continuously or at intervals by beacon stations was discussed. About 120 British ships are equipped with direction finders. A number of the speakers gave their remarks from actual experience. We give below a reprint of the paper:—

(1) Retrospect.

The following notes concern the development of direction-finding on the Bellini-Tosi system, in which two fixed loop aerials at right angles to one another are used in conjunction with a rotable search coil. The results mentioned have been obtained with spark (as opposed to continuous-wave or interrupted continuous-wave) telegraphy.

The first attempts were made with loop aerials, each tuned independently to the frequency of the signal the direction of which it was desired to obtain, the loop aerials being very loosely coupled to the search coil and its circuits. This system, which had given admirable results on land, was found when fitted in an iron ship to be too difficult to work and to possess too grave errors of a quadrantal nature to be of practical value for navigational purposes, the only justification for its existence in the mercantile marine.

The method of using untuned loops, usually, though incorrectly, called aperiodic loops, was then resorted to, and promising results were at once obtained.

(2) Errors Encountered.

(*a*) *Calibration error.*—In all that follows the word "loop" is used to convey the idea of the whole arrangement used to absorb energy from the ether, including the field coil, lead-covered cable and junction boxes, as well as the simple loop itself. The capacity present in this circuit is a complex quantity, of which the greater part is the capacity between the core and core of the lead-covered cable. Such a circuit has a well-marked natural frequency. The expression "simple loop" is used to denote that portion of the whole which is purposely opened out so as to enclose a considerable area.

An analysis of the nature of the errors obtained when identical loops were used brought forward the fundamental conception on which all subsequent work has been based; that is to say, the idea that the ship herself with all her rigging might be imagined to be replaced by a fictitious simple loop lying in the vertical plane and parallel to the keel line of the vessel. The action of this fictitious simple loop is taken into consideration when determining the area of the fore-and-aft loop of the complete direction-finder system.

Since this fictitious simple loop is fore-and-aft, and since its effects cannot be ignored or eliminated and must not be allowed to produce an effect equivalent to mutual induction between the two tangible simple loops of the aerial system, it is clear that one of the two tangible simple loops must be parallel to the fictitious simple loop, that is to say, fore-and-aft. Therefore the other tangible simple loop must be athwartships.

Since the tangible fore-and-aft simple loop is coplanar with the fictitious ship simple loop, there will be considerable coupling between these two, and therefore the current circulating round the tangible fore-and-aft loop will, under any given conditions, be greater in some geometrical proportion than would be expected from a consideration of the dimensions of the fore-and-aft loop alone.

If identical loops were used the result of the above would be that the directions as observed would tend to be crowded towards the fore-and-aft line, the error being a maximum when the correct relative bearing is on the bow or quarter, and vanishing when the correct relative bearing is abeam, or ahead, or astern.

This error, which is now in practice usually given the name of "calibration error," can be completely removed by reducing the area of the tangible fore-and-aft loop, or by adding to its impedance, or by a combination of these two methods. It is usual in practice to employ the largest convenient thwartship loop (up to an area of about 400 sq. ft.), and to adjust the size of the fore-and-aft loop until a slight calibration error remains, finally removing it by adding impedance equally to the two limbs of the fore-and-aft loop.

(*b*) *Loop-tuning error.*—The last paragraph shows that the two loops are essentially of different dimensions and therefore, in all probability, of different natural frequencies. If both the loops are

very considerably different in frequency from that of the signal to be received, the current circulating in each will be almost in quadrature with the voltage applied by the incoming wave, and therefore the currents flowing round the two loops will be almost exactly in phase with one another. Further, the value of the current reached in each loop will be almost exactly proportional to the voltage applied to that loop by the incoming wave.

In the first of these two conditions (similarity of phase of circulating currents) is not made good, the familiar rotating-field effect will be produced on the search coil. Since the position of zero coupling between the search coil and the field coils which are connected to the loops is the index by which directions are measured, the effect of such a rotating field is to fog the observation by obscuring the position of zero signals.

Also, if one loop happened to be of the same, or very nearly the same, frequency as the incoming wave, the circulating current round it would be greater, in proportion to the voltage applied, than the current in the other loop (by hypothesis of different frequency) and therefore less nearly in resonance with the incoming wave. Therefore the proportionality between impressed voltage and circulating current will be different in the two loops, and a quadrantal error similar in effect to calibration error will result. Its extent will vary with alteration of wave-length of the received signal, and will vanish if the frequency of the incoming wave is midway between the frequencies of the two loops. As such an error varies with wave-length, it is quite inadmissible. These two effects of one cause are in practice lumped together under the name of "loop-tuning error." They can be completely avoided by fitting loops of suitable dimension in the first place, and are almost unheard-of in practice.

(c) *Lack-of-symmetry error.*—If we consider the current flowing in any part of a vertical loop under the influence of an incoming ether wave, it is clear that there are two distinct components. One is a circulating current round the loop. The cause of this current is as follows :—

If we imagine each half of the simple loop from apex to junction box to be replaced by its phantom vertical projection, the incoming wave will induce a voltage between the two ends of each phantom projection, the potential to which each of these four ends is raised at any instant, by effects of the incoming wave being different. If the plane of the simple loop is not parallel to the wave-front the voltages induced in the two phantom vertical projections will be unequal, and the difference between them is the useful voltage available for the production of a circulating current. For brevity this current is in practice called the "loop current," and clearly the instantaneous value of the voltage causing it depends upon the height and distance apart of the phantom projections (in practice, the area of the loop) and the rate of change of intensity of electric and magnetic stresses caused by the incoming wave at the instant under consideration.

The other component is a simple alternating current flowing in both sides of the complete loop from the apex to the mid-point of the field coils, the actual current distribution being to a great extent governed by the capacity to earth of the various parts of the loop. For the sake of brevity this current is in practice called the "plain current," and the instantaneous voltage to which it is due is caused by the instantaneous value of the electric and magnetic stresses set up by the incoming wave.

Hence we see that the "loop" voltage and the "plain" voltage are in quadrature, the loop current leading or lagging relatively to the loop voltage in accordance with the electrical constants of the loop circuit, while the plain current will lead or lag relatively to the plain voltage in accordance with the electrical constants of the plain circuit.

If the construction of the loop and its attendant field coil is perfectly symmetrical electrically, the plain current will be equally divided between the two halves of the loop, and the effects of each half of the field coil on the search coil will neutralise one another.

Absence of this condition of symmetry is the most troublesome, the most common, and the most dangerous source of error. It is generally called in practice "lack-of-symmetry" error, and the satisfactory operation of direction-finders on board ship is almost entirely a question of the success with which causes tending to produce or accentuate this error can be counteracted.

In order to protect the insulation of the connections between the loops and the direction-finder instrument, and also the windings of the field coils themselves, from the effects of accumulated static charges or the induction due to transmission, the centre of each field winding was at first connected direct to earth. This direct connection accentuated the effects of lack of symmetry, and has since been replaced by a suitable inductive choke.

The causes of lack of symmetry are twofold: "permanent" lack of symmetry due to unequal distribution of any electrical dimensions between the two sides of a loop, which would result in unequal impedance in the two halves, measured from apex to mid-point; and "inductive" lack of symmetry due to re-radiation and or induction from individual conducting portions of the ship's structure, which may have unequal effects upon the two halves of a loop. The effects of the former are apparent, irrespective of the strength of signals, but the effects of the latter increase with the strength of signals and are often only noticeable with very strong signals. This state of affairs appears to be explained as follows :—

Consider an athwartship loop which is inductively unsymmetrical, the relative bearing being considered to be right ahead. There is zero loop current in this loop, but the effect of inductive lack of symmetry is to cause an unequal distribution of plain current between its two halves, and therefore there is a magnetic coupling between the field coil and the search coil. The effects of this current may be too slight to deflect the resultant magnetic field through the field coils to any appreciable extent, and no error is then observable, but when the effect of the inductive lack of symmetry becomes sufficient to deflect the resultant magnetic field through the field coils the error begins to appear. There is, in short, a marked threshold effect observable in cases of inductive lack of symmetry. In cases of permanent lack of symmetry, the disturbance due to unequal distribution of plain current

increases in the same proportion as the loop current, being due directly to the plain voltage and not to the effects of an outside conductor itself under the influence of the wave, and no threshold effect is observed. Inductive lack of symmetry is the source of the most elusive and the most dangerous errors which have been experienced in the application of direction-finding to navigation.

Having decided on the position of the loops, the next point is to decide on their form. This is a matter of but very little importance provided that extremes are avoided, but it is very desirable that there should be a pronounced geometrical apex to each loop. For sea-going work it is essential that the thwartship loop should have a well-marked apex, and it is advisable that the fore-and-aft loop should have one also. The reason is simple. Consider a flat-topped thwartship loop. If the vessel is on an even keel the top of the loop is horizontal and the electrical apex is in the centre of the horizontal limb. If now the ship heels over, even to a very small angle, the apex becomes the weather corner and symmetry is destroyed. The same applies, but in a less degree, to the fore-and-aft loop.

Lack-of-symmetry error is the only error which can make a bearing appear to be in the wrong quadrant, and lack of symmetry in the thwartship loop may well be sufficient to make a bearing appear to be on the wrong bow.

If it can be assumed that the loops are symmetrically rigged truly fore-and-aft and athwartships, and with the geometric axis of each loop directly over the point where the ends of the loop join its cable, and that they can be kept taut, then the possibility of errors due to lack of symmetry is reduced to a minimum; and as permanent lack of symmetry can be detected by easily applied internal tests of sufficient delicacy, the actual danger due to lack of symmetry in all its forms is zero.

Lack-of-symmetry error takes many forms according to its extent, and whether one or both loops are at fault. The strange diversity of results is hardly worth recording now that symmetry testing has been established, but it is worth noting that a combination of a slight lack-of-symmetry error and a slight electrostatic error often has the effect of leaving one zero accurate and sharp and the other very "woolly." It is sometimes necessary to accept this as a temporary measure, and to let well alone.

(*d*) *Plain tuning error.*—The remaining inherent error is due to the effects caused by the frequency of one loop, viewed as a simple plain aerial, being very nearly in tune with the incoming wave when the frequency of the other loop is somewhat less nearly in tune. This error is comparable with loop-tuning error and is negligible if loops of proper dimensions are used. The adoption of the inductive choke mentioned in the preceding paragraph renders the loops viewed as "plain" aerials practically aperiodic (in the true sense of the word) and is now almost unheard of. The effects are zero if perfect symmetry exists; if not, it accentuates the lack-of-symmetry error on certain waves. It is generally called "plain tuning error."

(*e*) *Electrostatic error.*—There are also two inherent instrumental errors. Of these the more important is the result of superposing the stray capacity coupling between the field coils and the search coil upon the magnetic coupling. The effect of this stray capacity coupling is to distort both positions of zero resultant coupling, and, although the line bisecting the angle between the observed zeros is at right angles to the proper zero due to magnetic coupling only, the presence of this error is detrimental to rapid and accurate work. It can be practically annihilated by the interposition of an earthed shield between the windings of the transformer connecting the search coil with the tuning condenser. It is most noticeable when the stray capacity is large in proportion to the tuning capacity that is to say on the shorter waves, when the tuning capacity is very small. This is commonly called the electrostatic error.

(*f*) *Capacity error.*—The second instrumental error is due to the varying capacity coupling between the search coil and first one and then the other of the field coils. By spreading out the windings of the search coil on one side of its former in a V shape, this error, which is never as much as 1°, can be made to reach its maximum and fall to zero eight times in the 360°, and so long as "swing" readings are used it is truly negligible, and in practice no notice is taken of it. This is the cause of the important difference in practical working between systems employing "tuned" and "untuned" loops. In the former case the arc through which the search coil can be moved, while still preserving inaudibility of a naturally good signal, is very small—perhaps only 2° to 3°—and under these conditions what are familiarly known as "sitting" readings can be taken. In the latter case the arc of inaudibility is usually 20°-40° and "sitting" readings are impossible; only swing readings can be used, and these of necessity eliminate the second instrumental error.

The colloquial term "swing readings" means observing the position of the pointer which gives equal strength of signals on either side of the arc of inaudibility, and taking the mean of these two positions as the position of true zero. It is usual to observe the position in which the signal just becomes inaudible. Bearings are perfectly reliable with vanishing points up to 60° apart.

(3) Construction of Loops.

From the foregoing it is clear that, given a properly constructed direction-finder, everything depends upon the erection of electrically symmetrical loops of the correct relative areas, the planes of the loops being necessarily vertical and at right angles to one another. One must be exactly fore-and-aft and the other exactly athwartships, but there is no reason why their planes should intersect, and no practical disadvantage is found if they do not do so, so long as the distance between their axes is small in comparison with a quarter wave-length.

It should be noted that there is no obvious theoretical reason why the fore-and-aft loop should be on the centre line of the ship, though common sense indicates that it is desirable to place it there. No experiments have been tried with fore-and-aft loops out of the centre line, as every effort has been concentrated on producing a seamanlike and trustworthy aid to navigation, and no opportunity has

offered for academic investigation. One fore-and-aft loop accidentally fitted a little off the centre line gave indifferent results.

Under ordinary sea-going conditions a subsidiary difficulty is experienced. If the loops cannot be made permanent, but have to be lowered and re-hoisted frequently, there is a great likelihood of the symmetry being destroyed in the process. This has been found to be a very real and serious cause of trouble.

Summarising the above, it is clear that the main practical difficulty lies in the selection of a suitable position for the loops and in the appropriate arrangements for rigging them. Before selecting the position of the loops it is first necessary to decide on the position of the direction-finding instrument. As far as the mercantile marine is concerned, it is highly desirable to have the instrument in the wireless room. It should be under the charge of the telegraphist and always available for practice, and when using it he should be in his own place and not an intruder among the navigating staff. The position of the directing-finding instrument must to some extent limit the choice of positions for the loops, on account of the capacity of the connecting leads.

For this purpose twin lead-covered paper-insulated cable is used, the cores each consisting of one strand of 20 L.S.G. copper, and with this cable a total length of 100 ft. is permissible from the direction-finder to the commencement of the loops. This figure is based on the assumption that the loops are to be large enough to allow good bearings to be obtained up to a distance of 100 miles on spark waves between 400 and 1,000 m , and small enough to avoid " loop-tuning " error in 400 m.

Experience shows that the larger the ship the larger should the loops be for a high degree of accuracy. Small loops, even down to an area of 70 sq. ft., have given accurate service at ranges up to 30 miles in small ships, though they are not accurate in large ships. The reason for this appears to be best explained if the state of the electric field among the rigging, funnel, boat gear, etc., of a large ship be regarded as a mass of eddies, in which loops large in proportion to their surroundings are affected by many such eddies tending to balance one another and thus give an accurate average result, whereas loops small in comparison with their surroundings are more likely to feel the effect of a single eddy and thus give inaccurate bearings.

Experience has shown that loops work well for all frequencies lower than their own natural frequency, but they are very unsatisfactory for frequencies higher than their own. Obviously, the capacity from core to core of the lead-covered cables is a very important factor in determining the " loop " frequency of each aerial, and the capacity from cores to lead covering is of similar importance in determining the " plain " frequency of each aerial. The core-to-core capacity also acts as a shunt to the field coils, and, briefly speaking, the shorter the cables the better are the results.

Having complied with the limits imposed by the permissible length of cable, a search must be made for some place where the loops can be erected and in which it will not be necessary to lower them. For work under mercantile marine conditions as outlined above (400 to 1,000 m. spark), the area of the loops should lie between 200 and 400 sq. ft.

No part of the loop should come within 6 ft. of earthed metal, and if the disposition of such earthed metal is not symmetrical about the axis of the loop, this distance must be increased to at least 12 ft. This figure is not yet definitely fixed, but there is clear evidence of evil effects at distances up to 10 ft., and it is quite possible that the safe distance may be as great as 20 ft.

If unsymmetrical objects, such as ventilators or hatches, are unavoidable, they must be screened by the interposition of an earthed plane—say wires 1 ft. apart—at least 6 ft. wide and symmetrically disposed on each side of the axis of the loop which it is intended to shield. Satisfactory results are obtained if the screen is mid-way between the nearest limb of the loop and the object from which it is to be shielded. If these precautions are neglected, evanescent errors may occur due to, for instance, the opening and shutting of large iron skylights, turning of ventilators, etc.

(*To be concluded*).

Correspondence.

Letters of interest to experimenters are always welcome. In publishing such communications the Editors do not necessarily endorse any technical or general statements which they may contain.

To the Editor of EXPERIMENTAL WIRELESS.

SIR,—With reference to the interesting article on wireless telephone receivers by Mr. Gayes in your last number, one can but agree with the writer that the standard methods of applying these in valve circuits are technically unsatisfactory; but may I be permitted to point out that the actual polarising arrangement suggested by your contributor would, as applied to a pair of head-telephones, result in acoustic assynchronism ?

The receivers, whilst in series relative to the polarising current, are now in parallel, and of opposite polarity relative to the speech-currents, neither is it possible in this arrangement to introduce correction in one relation without introduction of error in the other; so that at time t in each cycle the speech currents will be co-polar in the one case, and counter-polar in the other, reversal without commutation occurring at time t^1; and whilst symmetrical displacement of the diaphragms may be obtained the movements will be opposite in phase, and the accoustic resultant theoretically zero if the amplitudes are equal, as shown in Fig. 1.

In practice, the human senses are to a consider-

able extent able to contend with assymmetry, and to a less extent with assynchrony, though they cannot commutate, and this will prevent the *aural* result being zero; but the result will actually be such that one ear or receiver of a pair will assume command, and the other will be practically non-effective when applied simultaneously—the effect being in this respect comparable to that observed in a wrongly interconnected pair of receivers wherein the connections to one earpiece are reversed, with the difference that whereas in such case both assynchrony and assymetry may be present and the senses will in that case be assisted differentially, in the present case assynchrony only will be present, and, whilst the receivers will be equally effective individually, collectively one or other of them must

Mr. Gayes' arrangement is, moreover, applicable to a *pair* of receivers only, and could not be used in connection, for example, with a single loud speaker, as the polarising battery of negligible resistance would then be in shunt with the receiver, whereas the arrangement now suggested is applicable in either case, the receiver or receivers being in series relative to both speech and polarising currents.

A development of this arrangement which works well in practice and is actually used by the writer for both headphone and loud speaker work is shown in Fig. 3. Here the choke itself is used to minimise the losses occurring across the resistance, and a somewhat different action is set up. Since both anode and polarising currents now traverse the

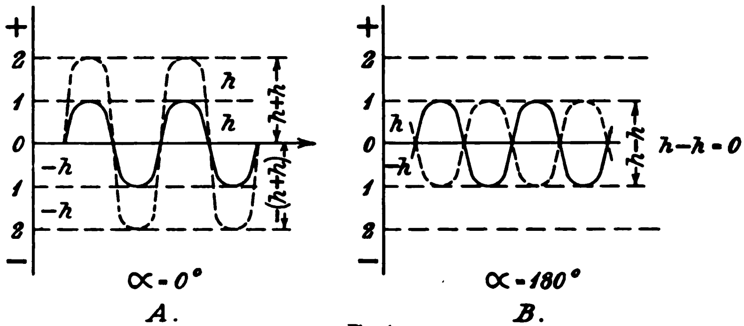


Fig. 1.

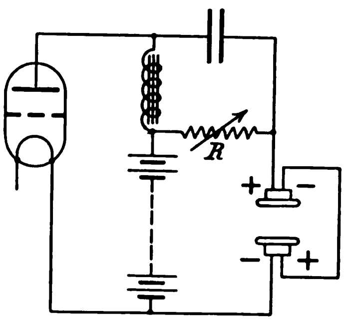


Fig. 2.

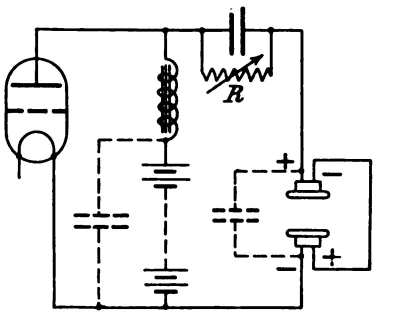


Fig. 3.

be aurally non-effective, in the sense that both cannot be heard simultaneously; and the practical effect of this, in addition to an apparent loss in volume of at least 50 per cent., is extremely unpleasant and fatiguing.

May I venture to suggest that a better arrangement from this point of view would be such as is shown in Fig. 2? Here a resistance R is certainly in shunt with the telephones, and a certain loss of speech currents inevitable even when such resistance is made considerably greater than the impedance of the telephones thereto, but this is discounted by the fact that the action of the receivers is now synchronous; and in practice, whilst the net result is not actually a gain in signal strength, considerable improvement in the quality of reproduction is obtainable without loss in volume as compared with the usual connections.

choke, we have in effect reproduced the conditions obtaining in a choke controlled transmitter, and audio-frequency variations in the anode current give rise to equal and opposite variations in the telephone current, the steady mean polarising current being, however, adjustable by means of R independently both of the steady mean anode current and of the speech currents in the telephone circuit, the ideal degree of polarisation being thus obtainable without loss of the speech currents themselves or other complications ensuing.

This arrangement was originally suggested by the writer a year ago to Mr. Gerald Marcuse in connection with loud speakers of the auto-excited type usual in this country, with which it was suggested that considerable improvement in reproduction and efficiency might be obtained by these means; and the theories involved in this suggestion

and in Mr. Gayes' article are borne out in practice with all forms of magnetic receiver.

A practical disadvantage of any such arrangement, however, is the extra drain imposed upon the anode battery, which in the generality of cases, where this consists of small dry cells, becomes a serious consideration, and it is regarded as questionable whether the actual advantage gained is such as to justify this in the majority of cases—exceptions being, of course, provided for special purposes and where (as happens in the writer's case) the H.T. supply is practically unlimited.

Since the arrangement proposed by Mr. Gayes, whilst unsuitable for general use, is eminently suitable in the case of two or more loud speakers so disposed that assynchrony becomes unimportant, it is thought possible that its conception may originally have been in view of such an application rather than in connection with actual headphone receivers—though it will be appreciated that the effect in the case of loud speakers disposed within *audible range* one of another would necessarily be similar, in less marked degree, to that obtaining in the latter case—and this letter is written by no means in a spirit of criticism, but solely in discussion of a subject interestingly opened by your contributor about which little has yet been heard in amateur circles.

ALAN ST. CLAIR FINLAY,
Captain.

To the Editor of EXPERIMENTAL WIRELESS.

DEAR SIR.—I have read with considerable interest Capt. Finlay's letter concerning my article on Telephone Receivers. I must thank Capt. Finlay for contributing additional information, particularly for Fig. 3. This, in my opinion, represents an excellent method of applying telephone receivers to wireless circuits and has an advantage over the method I selected in that there is no necessity to use two receivers in parallel, and thus a high impedance output circuit can be maintained if necessary.

Capt. Finlay's rather startling assertion that receivers connected in the manner I suggest would give an acoustic resultant approximating zero, is, I think, of theoretical interest only, as in practice such effects very seldom occur and then often when they are least expected. Were we interested in two similar sources of sound of equal periodicity, displaced 180° and so disposed as to eliminate sound reflections, then the zero effect referred to by Capt. Finlay would be noticeable, but experience with telephone receivers as sources of sound show the problem to be more involved, and, as I will show later, the conditions are not always what they appear to be at first glance.

I would refer for a moment to a form of loud speaker frequently seen on the market, which consists of a common air chamber energised by a pair of ordinary head receivers fitted on the ends of a "T"-shaped arm. Here is an ideal case for assynchrony, but those who have experimented have probably found any such effect very erratic in its appearance, and it was the writer's experience that a particular pair of head receivers had to be deliberately wrongly poled before the full volume of sound was obtainable from this apparatus.

A second set of experiments having bearing on the problem may be of interest. These tests were made recently by an expert experimenter when studying the binaural effect of sound. This latter effect is mentioned by Capt. Finlay, and for this reason the following notes may be of special interest. Two triode oscillators each of smoothly controllable frequency were set up. First, a pair of series head 'phones were joined to a coupling coil so placed as to receive equal induction from each oscillator. The oscillators were adjusted to beat, and, of course, the beats were readily detectable. Next, the two head 'phones on a common head band were joined to separate coupling coils each of which was coupled to an oscillator, the two systems being widely separated to avoid mutual induction. With this arrangement it was still possible to get beats although their presence was dependent upon the magnitude of the sound. In other words there appeared to be a saturation limit to the ear above which the beats were not apparent. Experiments were made at various frequencies with similar results. *No difference whatever* was apparent on reversing *one* of the receivers, either as regards intensity of sound or ability to set up beats.

Without taking further apparent anomalies it might be advisable to attempt to explain what takes place. Every telephone receiver has its own particular natural frequency of vibration, and it will be seen from the reports which have recently been made public before the I.E.E. by our research workers in their discussions on Loud Speakers, the phase relationship between the energising current and the movement of the diaphragm is considerably affected by this point of resonance. Thus we see that two receivers poled and energised to be in perfect phase at one frequency will be hopelessly out of phase at some other frequency. Therefore, for any complex sound, such as those in which we are interested, it must be a practical impossibility to secure two receivers functioning 180° out of phase.

As a matter of fact "phase" in telephony is of very little consequence, as the aural faculties are essentially integrating and responsive to sounds lasting over a certain period of time. This statement must, of course, not be confused with the mutual destruction of the sound waves in a common medium. Here the effect is not integrated, but is an instantaneous one.

Should any proof of these statements seem desirable reference should be made to a complete work on the subject, by M. G. Lloyd and P. G. Agnew, entitled the "Effect of Phase of Harmonics upon Acoustic Quality," a paper published under No. 127 by the American Bureaux of Standards. Here the authors studied the effects of phase by taking a supply from a Franke machine, so arranged that the phase of the harmonic was under perfect control. The general conclusion is that aurally the phase relationship of sounds is of no consequence whatever.

ALEXANDER J. GAYES.

To the Editor EXPERIMENTAL WIRELESS.

SIR,—In reply to the letter from Mr. J. A. Partridge in the last issue of this journal concerning transatlantic radiotelephony, the author regrets that he cannot at present undertake to provide fuller information than has already been published.

The experiments concerned were essentially of a private and confidential nature undertaken for the

investigation of a radiotelephony system evolved by the writer, and divulgence of further details of any kind at the present juncture would not be in the best interests.

The writer is therefore able to assure Mr. Partridge that neither the American Radio Relay League nor any other body has fuller information at its disposal than has already been provided, and wishes to make it clear that establishment of individual "records" of any kind was not amongst the objects of the experiments, which were of a purely scientific nature.

The article in question, in so far as it was applicable to standard methods, was published in the hope that it might prove of some interest, and perhaps use, to other experimenters; but it will be appreciated than an investigator cannot always be prepared to disclose full details of his work until ready to do so—a prerogative which the author has no alternative but to exercise in the present case.

It is, however, far from the writer's wish to appear discourteous, and Mr. Partridge—whose interest in the matter is much appreciated—may rest assured that adequate information on the subject will be published in due course, when not only will it be fully available to him, but the writer will be happy to afford him a personal opportunity of witnessing a demonstration of the system, both as regards the results achieved and the means whereby they are obtained, which it is hoped Mr. Partridge may see his way open to accept.—I am, Sir, yours faithfully,

ALAN ST. CLAIR FINLAY.

To the Editor EXPERIMENTAL WIRELESS.

SIR,—With reference to Mr. Scroggie's comments concerning the article on transatlantic radiotelephony, recently published in this journal, the author is, unfortunately, not at present free to discuss these as fully as he would wish for reasons which are stated elsewhere in these columns; but to reply to the points raised by your correspondent as far as circumstances will permit:—

(1) The writer is unable to agree that the useful effect in the receiver of a modulated wave can be shown to be proportional to the product of aerial current and modulated amplitude, as such effect must in fact be regarded as proportional to the square of the product of the steady component and the determining amplitude, which will lie in the modulated component.

The relative effects of the two examples chosen are therefore not 0·8 and 1·4, but as ·25 and ·49, although this still appears favourable to your correspondent's contention; but when the power expenditure involved in the two cases is taken into consideration (that in the latter will, of course, be equal to four times that in the former) the relative efficiencies of the two from the transmission standpoint may be computed, and the author's statement in the matter be understood.

Lest the derivation of the figure ·25 given above be considered obscure, it should be pointed out that, where the modulated component is the major component, the determining amplitude must be equal to exactly ·25 of the total output, which proportion it cannot exceed, and that the effect of over-modulation such as 80 per cent. will therefore be disproportionate rendering of the major and minor amplitudes, resulting, not in loss of general signal-strength, but in distortion.

This under ordinary conditions is inevitable where more than 50 per cent. of the output is modulated, and is a matter quite apart from pre-control distortion discussed in the article, although, the ear being unable to detect disproportion of this nature up to an order of 300 per cent., modulation depths up to 70 per cent. are in practice permissible in the majority of applications, and result in a certain increase in efficiency.

(2) The meaning of the reference to modulation frequencies and antenna tuning is not clear, since the antenna is normally tuned not to the modulation frequencies but to the carrier frequency. It is, of course, common knowledge that side-frequencies are formed and a carrier "spread" by modulation, but reference to this elementary fact was not made in the article, the passage in question actually referring to tuning of the oscillatory circuits —aerial inclusive—to the carrier frequency, and being intended to emphasise that control should be exercised as far as possible upon amplitude and not upon frequency—*i.e.*, that the carrier should be maintained at a constant frequency to which the circuits should in the general case be resonant, and should not be caused by the operation of the control to occupy a band of frequencies, the reasons for which will surely be evident.

(3) Mr. Scroggie's statement that "the same amount of power is absorbed by the aerial ammeter in giving a reading however it is connected" is erroneous in this application. In the former case the decrement varies directly with the resistance of the instrument, whereas in the latter it varies inversely, where the instrument constitutes a resistance in series and in shunt respectively; and the advantage to be gained under these conditions by connection of an instrument of high resistance in an indictively-coupled loop rather than directly in series should be evident.

Moreover, the transformer-loss in such case does not operate against the main-circuit current, but against the loop current, and can be allowed for.

The coupling and instrument concerned naturally require appropriate setting and calibration, and that this is actually done is stated in the article—variation in the coupling being in fact utilised to provide a double-reading scale suitable for wide power variations and a correction applicable to the use of different frequencies. The writer is unable to agree that this method need be in the least degree more uncertain than the series if correctly applied, and would assure Mr. Scroggie that it is, in fact, standard practice and in no way novel.

(4) With regard to leakage of H.F. currents, *via* the LT+ lead, the writer would point out that the object of the choke L7 in the LT− lead is primarily to relieve the source of filament current supply of small H.F. PD's set up across the filaments and associated resistances, which are undesirable, and is purely a refinement. Since the low-potential side of the entire system is earthed, the question of leakage to earth scarcely arises, and neither the meaning of the reference thereto nor the object of a choke in the LT+ leads are clear. The writer would, moreover, point out that the common pole of the H.F. E.M.F. in a valve oscillatory system

is the filament, and the common portion of the oscillatory circuits include, *ipso facto*, the negative lead thereto or part thereof, but not the positive.

(5) The misconception concerning the function of the variable resistance shown shunting the voltmeter in Fig. 3 is not the fault of your correspondent, as a millimeter should have appeared in HT+ lead immediately above this, as stated below that diagram. Actually, the arrangement is designed for the determination of the anode supply voltage under load, and takes the place of an electrostatic voltmeter, varying loads down to that imposed by the instrument itself, representative of valve loads, being reproducible by variation of the resistance when the switch is closed, and the supply voltage at any load may thus be checked. But it is surely not conceivable that such an arrangement could reasonably be intended to have the function attributed to it by your correspondent ?

(6) The writer much regrets that the inductance of a speech-choke of 17,500 turns should accidentally have been given as 12 *micro*-henries instead of henries, but it is felt that this should scarcely affect the sense of an article intelligently read, since one cannot but agree with your correspondent that the intention is somewhat obvious.

The writer is indebted to Mr. Scroggie for the opportunity of clearing up certain points which, owing to considerations of space, may not have been adequately dealt with in the article itself, and wishes that certain of these could be discussed more fully than is at present expedient.—I am, Sir, yours faithfully,

ALAN ST. CLAIR FINLAY.

To the Editor EXPERIMENTAL WIRELESS.

DEAR SIR,—Your correspondent, " Short Wave," is guilty of two defects of logic. Firstly, he argues by analogy, and, secondly, he assumes as data various facts which, to make his analogy sound, it would be necessary to prove.

He also confuses " force," which has the dimensions MLT^{-2}, with " power," which has the dimensions ML^2T^{-3}.

Analysing his analogy : For the comparison of the displacement of coarse and fine thread screws it must be postulated : (1) That the volume of the screws per unit length is the same, and at first, that (2) no friction or other irreversible phenomena exist. This will give a theoretical answer. Then, by admitting friction, the practical answer can be deduced.

If no friction occurs the power given to the screw must be stored in strain energy in the wood, and if the same volume displacement takes place in the same time the strain energy will be the same and the power taken will be the same. In other words, for equal power the screws will travel in at the same rate. Now admit friction.

It is easily proved that the fine thread screw has for the same volume a greater surface area than the coarse thread and will therefore generate greater friction per unit length. It will therefore consume more energy in overcoming the force of friction than the coarse thread screw and will therefore take more power when progressing into the wood at a certain velocity than will the coarse screw when progressing at the same velocity. This is, as a matter of fact, fully borne out by practical experiment, and your correspondent's analogy is in exact opposition to the true facts.

He then goes on to suggest that long waves and short waves may travel at a different speed. He has engaged heavier metal than I am here, as the whole foundation of the electro-magnetic theory of light and other ether disturbances and of the theory of relativity is based on the fact that in the same medium disturbances of all wave-lengths travel at the same velocity. In different media, of course, this velocity varies ; hence the phenomena of refraction.

In any case, retardation of a wave is not the same as absorption, though the phenomenon usually occur together.

The problem is complicated by the fact that we signal through a tunnel, whose roof and floor are partial conductors (and therefore reflectors of our waves), through a medium which is, figuratively, sometimes thick, sometimes clear soup and very often a stratified mixture.

I would, however, suggest that it is well-known that really short waves (*i.e.*, light) experience selective absorption in most transparent media, *e.g.*, solution of a dye.

It has not till now been shown that air or any other medium has not a selective absorption on waves of length suitable for radio-signalling, and any fact of this sort would at once explain why certain waves are more favoured than others in long distance travel.

In fact, the power of penetration apparently possessed by waves of $\lambda = 50$ to 200 metres rather goes to prove that this selective absorption exists.—I am, Sir, Yours faithfully,

I. A. J. DUFF, B.A.

To the Editor EXPERIMENTAL WIRELESS.

DEAR SIR,—I wish to make the columns of your valuable journal the medium for thanking those experimenters who have written to me reporting on reception of telegraphy and telephony purporting to emanate from my experimental station 2KG.

This would be highly gratifying to me were it not for the fact that these reports prove the existence of something that I have suspected for some considerable time ; I refer to the misuse of my registered call sign by some person or persons who evidently are aware of my continued absence from the United Kingdom, and are taking advantage of this knowledge in making regular and persistent illicit transmissions using my call-sign for the same.

To those gentleman who have been so kind as to write me respecting these transmissions, and also to my former confrères, I take this opportunity of pointing out that I returned to marine wireless operating in November of 1922, when I joined the wireless staff of the Cunard Line, and served for 12 months continuously aboard their R.M.S. *Tyrrhenia*, where it is obvious I would have neither time our opportunity for making experimental transmissions. Nevertheless, I understand that during the whole of that time 2KG was regularly " on the air."

Naturally, I have the strongest objection to this misuse of my call-sign, and I would be more than grateful if my correspondents would continue to

advise me of transmissions made with my call, and should this meet the eye of the person or persons responsible I would proffer the information that I have a rather efficient experimental direction-finding receiver at my home address in Aberdare (South Wales) by means of which I can get bearings up to within a maximum error of two degrees, and as I am able to be at home for six days each month, I intend to take the necessary steps to trace the delinquent.

My sincere thanks are extended to all those gentlemen who have been to considerable trouble in forwarding me these reports.

Unfortunately they are much too numerous to admit of my replying to them individually, but in particular I thank the following experimenters: Messrs. Herbert Etheridge, of Hanwell, W.7; S. D. Simmons, of Ockenden Road, N.1; P. Sutherland, Clancarty Road, Fulham; William E. Edge, of Kensall Rise, N.W.10; W. Durban, 35, Ulysses Road, West Hampstead; S. E. Smith, of Gordon Avenue, Twickenham; W. White, Medway Street, Westminster; P. A. Camp, of Balchier Road, Dulwich; Station 5LF, of Barnes, and Station 5GL, of Newark-on-Trent. It is significant that the majority of my correspondents are in London or district.

It is noted that station 6IM works frequently with the station that signs himself with my call-sign (2KG).

Possibly 6IM is prepared to volunteer some information concerning the matter.

May I also take this means of pointing out to the guilty party that, on receipt of any further reports of reception of Morse or speech signed 2KG I fully intend taking the matter to the Department of the Inspector of Wireless Telegraphy.

With apologies for thus far trespassing on your valuable space.—I am, dear Sir, Yours faithfully,

A. E. Hay,
Chief Wireless Operator,
R.M.S. *Avoccta*, Yeoward Line.

Lisbon,
January 31, 1924.

EFFICIENT INDUCTANCES.

To the Editor, Experimental Wireless.

The mild " battle of the gauges " which has been proceeding for some time in the various wireless periodicals indicates that the importance of really efficient inductances is at last being realised by an increasing circle of amateurs. A well-known writer not so very long ago informed us that " It didn't matter much if the inductance was wound with 40 S.W.G. wire or what it was like since any losses could be made good by reaction," and it is just possible that inductances which require such gingering up are a prolific cause of the oscillation nuisance.

With the ever-growing mass of modern literature and the knowledge that valve R.T. is new, we stand in some danger of forgetting the researches of the pioneers. Now, high-frequency resistance was given considerable attention by J. Zenneck, amongst others, as far back as 1905, for he treated the matter exhaustively in his " Elektromagnetische Schwingungen," and later in his " Lehrbuch," of 1912.

In Seelig's English version of the latter work—1915—there is given a very interesting table (pp. 396-397) showing the increases in resistance of various wires at frequencies corresponding to 100 to 6,000 metres.

S.W.G. Approx.	MM.	"Steady Current" resistance length of 1 metre.	Effective Resistance at 300 metres W.L.
36	0·2	0·554	0·61
24	0·6	0·0615	0·156
19	1·0	0·0221	0·108
14	2·0	0·00554	0·0432

If, then, an inductance of exceedingly large diameter be considered for ordinary reception, it appears that although 19 S.W.G. used at 300 metres has an effective resistance nearly five times its steady value, it would be advantageous to use it in preference to 24 S.W.G., which shows an increase of less than three times, or than 36 S.W.G. which shows practically no increased resistance at all.

Before dismissing the conclusions of Zenneck lightly the reader should remember that upon such work was built up the finest system of spark telegraphy ever devised, which even at the present date is carried by something like 80 to 90 per cent. of the world's fitted shipping.

Very heavy currents, both damped and undamped, have been dealt with for many years past, so that any errors would have been brought to light long before the advent of broadcasting reception.

If we reduce the inductance to workaday dimensions, we find that the effective resistance becomes further increased (perhaps × 2) owing to the tendency for the current to flow round the innermost side of the winding, but here again the larger wire appears likely to score by reason of its greater circumference. In all this, there is, however, the implied condition that the inductance, whether large or small in diameter, shall have negligible self capacity, and it occurs to me that some workers who have recently pronounced for fairly small wire as against thicker may have had some difficulty in separating the apparent resistance due to self capacity from that due to the wire *per se*.

In passing, it may be noted that when the current travels in the skin of a wire, and is equally distributed, there is practically no magnetic field within the wire, and, therefore, but little eddy current loss due to the use of reasonably large wire.

Even copper-clad steel wires have been found to have but little greater H.F. resistance than solid copper in the straight, so that for low eddy current losses coils of not too small diameter are indicated.

It is possible that a comparison between a coil which happens to be wound with fairly fine wire but is of good design, as against one of the many " good enough for amateurs " varieties with which the market is flooded, might lead to ascribing merit to the smaller wire which more properly belongs to the better design.

So far as the writer knows, there are two short-wave multi-layer coils on the English market which have any real pretensions to low self capacities of the order of 2 $\mu\mu$F., one being issued by Gambrell, and the other by the Rimar firm (H. Type).

Two different methods of arriving at much the same result as regards spacing of layers and turns are used, and the makers appear to represent different schools of thought as regards the gauges which are best for H.F. work. The whole subject

is of great interest and importance, and also, one may add, of some difficulty on account of the lack of easily applied methods of self capacity measurement.

Two are in common use, the first due to Howe, making use of the natural time period of the coil, and the second, due to Meissner, depending on the increase in self capacity which follows immersion of the coil in an insulating fluid K, for which is greater than 1.

The drawbacks to the former method are, firstly, that since there can be no definite natural period to a coil which has no self capacity, small self capacities in small coils produce natural periods outside the range of ordinary wavemeters, and, secondly, that as all measurements are made at very different frequencies from those for which the coils will be used, the figures obtained are often quite misleading, if not wholly inaccurate.

The other method measures the self capacity at the frequency at which the coil is intended to be used and, being capable of adaptation to beat note methods, is of great delicacy.

The drawback here is that the starting point is assumed to be a copper coil surrounded by air in every direction, instead of a wire surrounded by cotton, wax, varnish, etc., in all of which cases the figures may err, sometimes very seriously, on the low side, so that experience and some precautions are necessary to secure a true result.

I apologise for trespassing on your space at such length, but do so in the hope that we may " draw " some of the more experienced workers on the subject, for does it not run Poor Inductance—Low Pressures — Weak Signals—More Valves — Bad Speech ?—I am, yours very truly,

WM. A. RICHARDSON,

18, Wellesley Road,
Ashford, Kent.

DEAR SIR,—I have often been able to get $\frac{3}{16}$th" sparks from a 100-ft. aerial, with an average height of 35 ft.

I have only noticed this effect while it is raining, snowing, hailing, or sleeting. Hail seems to produce the most E.M.F., and I have sometimes been able to get $\frac{1}{4}$" sparks during sharp hail showers.

I got the same results with a rubber-insulated aerial as with the other, showing that the current is set up by inductional effects, and not by the charged flakes of snow, etc., coming into contact with the aerial.

Re the effect noticed by Mr. A. L. Williams, mentioned in the last issue of EXPERIMENTAL WIRELESS, I have noticed the same effect when receiving on wave-lengths up to 1,000 metres, with the receiving set 5 ft. from the end of the lead-in.

Here is a use for harmonics which I have not seen mentioned previously :

The transmissions from the Birmingham broadcasting station and the S.P.T. Paris are often badly jammed by oscillation and spark transmissions ; with a three-valve set, however, I can receive the first harmonic of these stations quite loudly (on headphones) without any interference at all.—Yours truly, KILO WATT.

Bolton,
April 14, 1924.

Points from Letters.

We have received the following letter from the Jewell Electrical Instrument Co., which indicates the interest with which EXPERIMENTAL WIRELESS is followed overseas.

The Technical Editor, EXPERIMENTAL WIRELESS.

DEAR SIR,—I have before me your March number of EXPERIMENTAL WIRELESS, and have been reading it with much interest, as usual.

Your article on high frequency resistance, however, impels me to write and question some of your statements.

On p. 320 in the second column you state : " The only apparatus necessary is a high frequency ammeter, such as a hot wire ammeter—which, although notoriously inaccurate, may be calibrated, etc." A little further down you state : " In the case of the last method, if a reliable high frequency ammeter (if such a thing exists) is not available, etc."

I will admit that your statements hold with reference to ordinary expansion type of hot wire instruments. They most decidedly do not hold when applied to the modern thermo-couple type of high frequency ammeter, which has practically displaced the expansion type in the United States.

The old expansion type of high frequency hot wire instrument was notoriously inaccurate, and made a much better thermometer than an ammeter. It was always off zero, and usually had a considerable lag.

The modern type of thermo-couple instrument, as manufactured by ourselves and some of our worthy competitors, is a real instrument, and one which can be relied upon. It has no zero shift due to its basic principle. It has very little thermo lag. Its calibration may be relied on very closely, and in the small instruments, say, three inches in diameter, which are so popular with the American amateur, it is rare that an instrument is more than 2 per cent. in error. . . . . . . and we would suggest that you look into the matter of high frequency instruments more thoroughly, as we feel that you are either misinformed or unaware of recent developments in high frequency meters.—Yours very truly,

JEWELL ELECTRICAL INSTRUMENT CO.,
JOHN H. MILLER,
Electrical Engineer.

We publish the above letter in case any other readers should have been misled by the article in question. Mr. H. Andrewes, the contributor of the article, was referring to the cheap type of hot wire ammeter which is popular among many amateurs, and not to thermo-couples. The article was written

for the benefit of the impecunious amateur, and not for those who have at their disposal an unlimited supply of instruments.

It may interest both our readers and the Jewell Electrical Instrument Co. to know that thermo-junctions of various degrees of sensitivity are used in our own laboratory with reasonable accuracy.

Re FRAME AERIALS.

Mr. Jowett, of Halifax, sends us the following letter, giving details of his experiments with inside aerials. Readers' experience under similar conditions will be of interest.

To the Editor of EXPERIMENTAL WIRELESS.

DEAR SIR,—For some time I have experimented with inside aerials, and I notice most writers advise beginners to erect an outside aerial. After many tests with my own and friends' aerials I have come to the conclusion that if properly erected, ***and insulated***, an inside aerial is quite as efficient as an outside one, and signals are equally as loud. No doubt inside aerials are condemned because those trying them have erected them anyhow. My aerial is fixed on four pieces of wood about 2″ × 1″ × 2½ ft. long, nailed vertically on the purlins near the roof of my house in a large under-drawing which goes over the whole area of the house, almost like a large attic. There is no lead on the roof, except at the top perhaps. The pieces of wood are nailed on the purlins so as to form a square about five or six yards square. Pieces of old motor tyre were tacked on the woods first, as insulation. Enamelled wire (22) is used for the aerial. The commencing end was fastened to one of the pieces of wood about 9″ below the top, and then complete turns taken round, each being 8″ or 9″ below the previous turn. The finishing end is led through insulating tubing through a trap-door down an open staircase into a dining-room, being kept about 12″ away from a wall, and the end of the wire is attached to the receiver. The length of wire used in the aerial is about 200 ft. to 230 ft. The earth of the receiver consists of a piece of 7/22 cable fixed to a water-pipe, and the length of this cable to the pipe is about four yards. The length from pipe to ground outside is two yards. Now, using the tuned anode circuit given in your first issue, I can work a small Brown loud speaker with three valves (from Manchester, 32 miles) and get enough volume to fill a room 5 yards by 5 yards. By switching on a fourth valve (resistance coupled) the sound is too loud for comfort. Two valves will work the loud speaker quite audibly. Also with phones I can get Cardiff, London, etc., quite audibly on one valve, or Paris 450 on two valves: all this with clarity and purity of tone. Bournemouth comes in almost as loud as Manchester. I am situated at the top of a hill and about 200 trunk wires run down the road. I can also receive transmitting amateurs over a big area. No doubt this will be of interest to you, and I should like to have your views.—Yours faithfully,

ARNOLD JOWETT.

Business Brevities.

MONEY, HICKS & MILLS, LTD.

Messrs. Money, Hicks & Mills, Ltd., of 297, Haydon's Road, London, S.W.19, have sent us their latest price list of Ivorex and Ebonex scales and terminal labels. These labels, it may be mentioned, are engraved either on black or white, and give a very neat appearance to a receiving set.

* * *

"BATY'S PRODUCTS."

Readers are, no doubt, familiar with the peculiar tuned anode receiver described some time ago by Mr. Ernest J. Baty, B.Sc., of 157, Dunstable Road, Luton. We have recently received a price list of the various components which can now be obtained separately, as well as the complete receiver. The condensers are of the circular plate variety, the dielectric being a combination of mica and air. One plate is fixed, and the other is fitted to the end of a screwed rod, by means of which its distance from the other can be varied at will. The price of the ·001 μF size is 5s. 3d., post free.

* * *

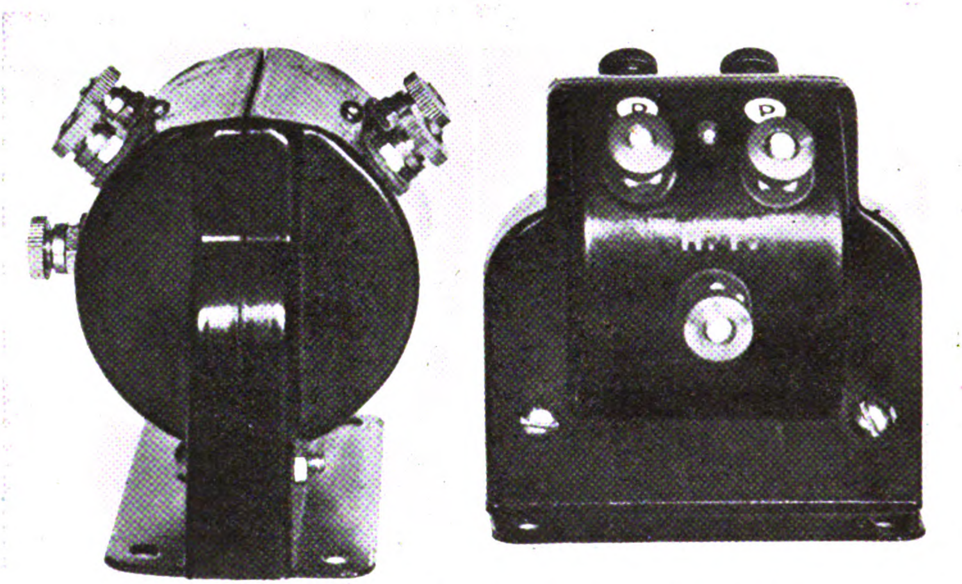
GENERAL RADIO COMPANY, LTD.

The head offices of the General Radio Co., Ltd., are now established in their new quarters Radio House, 235, Regent Street, London, W.1, and all communications should be addressed there. A showroom is provided, and all dealers are extended a cordial invitation to call. The General Radio Co., Ltd., distributes its products through dealers and factors, and does not sell direct to the public. Branches of the General Radio Co., Ltd., are located as follows: 6, Imperial Buildings, Oxford Road, Manchester; Cannon Chambers, Cannon Passage, Birmingham; 71, Middle Abbey Street, Dublin, Ireland; 37, Jamaica Street, Glasgow; 46, Above Bar, Southampton. A capable dealers' service department will gladly give demonstrations for dealers or their customers at any of the above addresses.

* * *

GRAFTON ELECTRIC COMPANY.

The latest edition of the Grafton Electric Company's catalogue, which we have recently received, contains some thirty pages devoted exclusively to wireless components. We notice that many of the leading manufacturers' productions are to be found among the list, which should prove of interest to our readers.



The push pull transformers by the Economic Electric, Ltd., are of the enclosed type.

THE ERLA TRANSFORMER.

It was with considerable interest that we tested the Erla transformer of the Electrical Research Laboratories, Chicago, Illinois, as it afforded us an opportunity of examining typical American apparatus. As will be seen from the accompanying illustration, the transformer is of the enclosed type, with the four terminals mounted on the top. The core seems to be of ample dimensions and did not appear to saturate when used in a power stage. The ratio of the turns is one to three and a half, but we did not have time to calculate the actual number of turns or to measure the impedance of the primary at various frequencies. The transformer was tested in three different stages of a speech amplifier and in each gave excellent results, the quality and volume being very good. In passing, we may mention that it functioned particularly well with a low impedance power valve.

The Erla transformer.

* * *

PUSH PULL TRANSFORMERS.

Messrs. Economic Electric, Ltd., of 10, Fitzroy Square, London, W.1, have recently put on the market a pair of push pull transformers which we show in the accompanying illustration, and are to be congratulated upon catering for the needs of the advanced experimenter. In order to test the transformers two similar amplifiers were arranged, one including the push pull transformers. Comparative tests showed that the push pull circuit effectively balanced out the distorted component, and the resulting speech was of much better quality and also of increased volume. Further tests showed that the secondaries are nicely balanced, but are, perhaps, a little on the small side, but this is not of really great importance. The price of the input or output transformer is 31s. 6d., and we can recommend either to any reader who is experimenting with differential amplification circuits.

* * *

"A.J.S." WIRELESS EQUIPMENT.

Messrs. A. J. Stevens & Co., Ltd., of Wolver-

hampton, have sent us their price list of sets and a copy of their instruction book. The latter gives very complete instructions for the successful installation and operation of their various receivers, and appeals to us as being an extremely valuable asset to those who are unaccustomed to radio receivers.

V. ZEITLIN & SONS.

Messrs. V. Zeitlin & Sons ask us to announce that they have now opened an additional showroom at 41, High Holborn, W.C.1, where their technical adviser, Mr. C. W. Thompson, will be pleased to assist their clients in technical matters.

Recent Wireless Publications.

Figures after the title of each publication indicate Volume and Number of Publication containing the article. Where only one number is given, this indicates the serial number of the publication. The abbreviations used in this bibliography will be found in the early issues of "Experimental Wireless."

I.—TRANSMISSION.

LOOSE-COUPLED TRANSMITTING CIRCUITS.—Maurice G. Goldberg. (*Q.S.T.*, 7, 9).

THE ELECTROSTATIC TRANSMITTER.—E. K. Sandeman, B.Sc. (*W. World*, 241).

FURTHER DISCUSSION ON "AN IMPROVED SYSTEM OF MODULATION IN RADIO TELEPHONY."—By Charles A. Culver, by R. A. Heising (*Proc. I.R.E.*, 12, 1).

ELECTROSTATIC TRANSMITTER AMPLIFIER CIRCUITS.—(*Exp. W.*, 1, 7).

RADIO-BROADCASTING STATION KGO.—Adam Stein, Jr. (*Gen. Elec. Rev.*, 27, 3).

II.—RECEPTION.

VARIATIONS SUR LE MONTAGE FLEWELLING (*R. Elec.*, 5, 56).

ALIMENTATION DES RÉCEPTEURS RADIOPHONIQUES PAR LE COURANT ALTERNATIF DU SECTEUR.—I. Podliasky (*R. Elec.*, 5, 57).

DISTORTIONLESS BROADCAST RECEPTION.—H. J. Round, M.C., M.I.E.E. (*Mod. W.*, 2, 7).

A NEW FRAME CIRCUIT.—J. H. Reyner, B.Sc. (*W. World*, 242).

SELECTIVITY.—L. J. Voss (*Exp. W.*, 1, 7).

IN SEARCH OF A REAL RECEIVER.—H. Andrewes, B.Sc. (*Exp. W.*, 1, 7).

FILTER CIRCUITS IN RADIO TELEGRAPHY.—N. W. McLACHLAN, M.I.E.E., F.Inst.P. (*Exp. W.*, 1, 7).

A TWO-VALVE RADIO-FREQUENCY AMPLIFIER.—P. D. Tyers (*Exp. W.*, 1, 7).

H.F. TRANSFORMERS.—P. K. Turner (*W. Trader*, 2, 14).

III.—MEASUREMENT AND CALIBRATION.

NOUVELLES MÉTHODES PERMETTANT DE MESURER EXACTEMENT LA RÉSISTANCE D'UNE ANTENNE OU D'UN CIRCUIT QUELCONQUE À HAUTE FRÉQUENCE WATTMÈTRE POUR HAUTE FRÉQUENCE.—H. CHIREIX (*R. Elec.* 5, 77).

RECEIVING MEASUREMENTS AND ATMOSPHERIC DISTURBANCES AT THE RADIO PHYSICAL LABORATORY, BUREAU OF STANDARDS, WASHINGTON, JULY AND AUGUST, 1923.—L. W. Austin (*Proc. I.R.E.*, 12, 1).

THE USE OF NEON TUBES FOR ELECTRICAL MEASUREMENTS.—Gerald R. Garratt (*Exp. W.*, 1, 7).

V.—GENERAL.

L'ATTRIBUTION DES LONGEURS D'ONDE AUX ÉTATS-UNIS.—(*R. Elec.*, 5, 56).

NOUVEL AMPÈREMÈTRE À THERMOÉLÉMENT POUR LES COURANTS DE HAUTE FRÉQUENCE (*R. Elec.*, 5, 57).

TELEVISION. AN ACCOUNT OF THE WORK OF D. MIHALY.—Nicholas Langer (*W. World*, 241).

A PRACTICAL DEMONSTRATION OF SOME APPLICATIONS OF THE CATHODE RAY OSCILLOGRAPH (DISCUSSION).—N. V. Kipping (*W. World*, 241).

AN EXPERIMENTAL DIRECTION FINDING STATION.—R. Keen, B. Eng. (*W. World*, 242 and 243).

THE POSSIBILITIES OF TELEVISION.—A. A. Campbell Swinton, F.R.S. (*W. World*, 243).

DESIGN OF LOOP ANTENNAS, PART III.—Ralph Batcher (*W. Age*, 11, 7).

THE RADIO EQUIPMENT OF THE STEAM YACHT "ELETTRA."—Eric A. Payne (*Proc. I.R.E.*, 12, 1)

THE DEVELOPMENT OF THE STANDARD DESIGN FOR SELF-SUPPORTING RADIO TOWERS FOR THE UNITED FRUIT AND TROPICAL RADIO TELEGRAPH COMPANIES.—Albert W. Buel (*Proc. I.R.E.*, 12, 1).

DIGESTS OF UNITED STATES PATENTS RELATING TO RADIO TELEGRAPHY AND TELEPHONY; ISSUED OCTOBER 30, 1923—DECEMBER 18, 1923.—John B. Brady (*Proc. I.R.E.*, 12, 1).

THE ELECTROMAGNETIC SCREENING OF RADIO APPARATUS.—R. L. Smith-Rose, Ph.D. (*Exp. W.*, 1, 7).

A VALVE GENERATOR FOR AUDIBLE FREQUENCIES.—E. Simeon (*Exp. W.*, 1, 7).

DULL EMITTER VALVES (*Electn.*, 2395).

SPEECH SOUNDS.—Sir Richard Paget (*Electn.*, 2395).

EXPERIMENTS ON SCREENING RADIO RECEIVING APPARATUS.—R. H. Barfield, M.Sc. (*J.I.E.E.*, 62, 327).

DISCUSSION ON "LOUD-SPEAKERS FOR WIRELESS AND OTHER PURPOSES" (*J.I.E.E.*, 62, 327).

A SINGULAR CASE OF ELECTRON TUBE OSCILLATIONS.—G. Breit (*J. Frank. Inst.*, 197, 3).

Experimental Notes and News.

In the Chancery Division, Mr. Justice Russell granted to the Igranic Electric Co., Ltd., of Bedford, and 149, Queen Victoria Street, London, an injunction against the London Variometer Company restraining them until judgment in the action from infringing the registered trade mark of the Igranic Electric Co., Ltd., and from selling or offering for sale electrical apparatus under or in connection with any circular, notice, or advertisement containing the word " Ivanic " or any other colourable imitation of the word " Igranic." And from supplying in response to orders for " Igranic " apparatus goods not of the manufacture of the Igranic Electric Co., Ltd., and from otherwise passing off goods not of the manufacture of the Igranic Electric Co., Ltd., as being of the manufacture of that company.

* * *

Mr. C. Ellison asks us to announce that the address of his experimental station 2JP is now Brockfield Hall, Dunnington, York.

* * *

The site of the Liverpool Relay Station still remains unsettled. It is understood, however, that the B.B.C. are negotiating for St. George's Church, which is one of the highest in the city, and would seem to be very suitable. It is not likely that the station will be in operation before June 1 at the very earliest.

* * *

It is understood from the British Broadcasting Company that the opening date of the Edinburgh relay broadcasting station will be May 1. Regret is expressed at the delay, which is said to be due to the fact that the delivery of the generators for the station have been held up. On account of strikes, and the failure to get material from abroad, delivery could not be promised so rapidly as the company were led to expect.

* * *

The Sheffield relay station 6FL, which works on 303 metres, is shortly to have its power increased from 100 to 200 watts, which suggestion has given great satisfaction to owners of wireless apparatus in the city, and particularly to those who are dependent upon crystal sets.

* * *

A contract has been granted to the Radio Communication Company of Great Britain for the erection and equipment of a chain of seven high-powered wireless stations on the islands of St. Kitts, Antigua, Dominica, St. Lucia, St. Vincent, Grenada and Barbados, the crescent-shaped archipelago which flanks the Caribbean. Private enterprise, it is stated, is to be confined to the erection, equipment, and initial testing. The stations are to be operated by the Pacific Cables Board, which is under the joint control of the Imperial Government and the Governments of Canada, Australia, and New Zealand. The contract cost is £62,670, which is shared by the Colonies concerned, the Canadian Government, and the Imperial Government.

* * *

The perfection is announced of an electric ultra-audible microphone, invented by Dr. Phillips Thomas, which, it is claimed, will permit scientists to record sound vibrations which now are too rapid or too faint for the human ear to catch. In its experimental stage the microphone has been used successfully to transmit by radio the highest notes of the voice and of musical instruments which the ordinary transmitter and receiver reproduce as mere noises.

* * *

For the first time the songs of birds have been broadcast. Major Corbett Smith, the Cardiff broadcasting station director, yesterday afternoon mounted the towers of Llandaff Cathedral and placed a microphone in position. The chimes of the cathedral sounded the hour of five, and there followed a full-throated chorus of birds hovering about the towers. All this was faithfully recorded in every listening-in set in Wales and the West of England.

* * *

Wireless enthusiasm in Southampton and district has been damped by the decision of a meeting of accumulator recharging businesses—mainly garages—to increase their charges. It was intended to increase the charge of 1s. 6d. for the most-used type of accumulator to 3s., and although, because of criticism, a slightly smaller increase may result, the prices will tend to restrict amateur wireless activities. The local radio society is organising enthusiasts to fight against any increase, holding that the more recharging that can be found the cheaper the operation should become.

* * *

Important developments in wireless in South Africa are likely in the near future, and a scheme is being discussed for communication between Salisbury and Pretoria by wireless by means of a six-kilowatt duplex installation at both towns. It is anticipated that the scheme will be in full working order in about a year's time, but it has yet to be approved by the Rhodesian Government. It is expected that the cost will be in the neighbourhood of £25,000.

* * *

During the spring it is hoped to broadcast the song of the nightingale. It is proposed to drive a motor car carrying a microphone and a transmitting set into the heart of Oxfordshire. The song of the nightingale would be received, if all went well, at some place near a trunk telephone line where it would be put on to the studio in London, and from there broadcast.

* * *

The total number of receiving licenses in existence on March 31 was approximately 720,000.

Experimental Wireless

A JOURNAL OF RADIO RESEARCH AND PROGRESS

Vol. I, No. 9. JUNE, 1924. 1s. NET.

Experimental Topics.

Developments in Radio Engineering.

Wireless telegraphy and telephony as we know it to-day is the outcome of experiment and research extending over a period of little more than a quarter of a century. Its history is crammed with ingenious inventions, those of the thermionic valve and the heterodyne method of reception, for example, standing out with particular prominence. It is upon such inventions as these that modern methods of radio telegraphy have been developed, and to these they owe their very existence. The progress of radio engineering, however, has recently undergone a considerable change, due entirely to the inauguration of a regular broadcast service. In the pre-broadcast era those interested in wireless telegraphy were comparatively few in number, and of these the majority were in some way or other intimately connected with the science in some professional capacity. To-day things are on a very different footing. In addition to the hundreds of thousands of broadcast listeners, there are thousands who have rushed into "the wireless business" in the hope that it may prove a remunerative proposition. Those who are in any way scientifically inclined have naturally become interested in the technical aspect of the subject, and any inventive faculty which may lie dormant is accordingly aroused. This would appear, on the surface, to be a very happy state of affairs, but, unfortunately, such is not always the case. The progress of radio engineering has been so rapid that it is almost impossible in the space of some eighteen months to become fully acquainted with everything that has been done, and harder still to appreciate its significance without a thorough understanding of the fundamental principles of physics and electricity. The inevitable result is that many an ardent experimenter works for months and months upon absolutely wrong lines, or alternatively, spends considerable time over some subject which has previously been investigated. The latter is probably the more unfortunate, since, although his labours seem to be crowned with success, he ultimately discovers that he has been anticipated years ago by some radio engineer, and more often than not his invention is far less perfect and far more crude. Such discoveries are usually the outcome of a desire for publicity. Overjoyed at the success of his particular scheme he very frequently conveys the details of his invention to the popular or daily press, where it is described in extravagant terms, and is not infrequently exaggerated and distorted. It is then that some scientific body or some engineer examines it critically, explains the circumstances in scientific terms, and little else is usually heard of the inventor or his scheme. It would not be expedient to cite any particular examples within recent times, but, no doubt, the last

few years afford many such cases. We would impress upon our readers the fact that any invention based upon sound scientific principles almost invariably becomes known through the channels of some scientific publication first, and subsequently finds its way into the popular and daily press. We assure our readers that we are fully alive to all that is taking place in almost every sphere of radio engineering, and any important development which, in our opinion, is both novel and worthy of consideration will be fully dealt with in the pages of this journal as soon as the circumstances warrant.

A Radio Research Fund.

We are pleased to hear from the Derby Wireless Club that they are proceeding with their scheme for the establishment of an Amateurs' Radio Research Fund as outlined in our issue of February last. We understand that approval of the movement has been expressed at the Conference of the Radio Society of Great Britain held in March, and also by members of nearly all the wireless clubs and societies with whom the Derby Club have corresponded. The stage of issuing collecting cards has now been reached, and donations have already commenced to come in. All this is so much to the good, but we are not at all sure that in their enthusiasm the Derby Club are not moving a little too rapidly. People who are asked to subscribe to any kind of fund are usually inquisitive, and among the things which collectors for this research fund are likely to be asked are: what is the Fund going to be used for, and who is going to control the expenditure? We have no doubt in our own mind that any funds collected in response to the Derby Club's appeal will be well and faithfully applied, but there are thousands of wireless amateurs in the country who might be asked to subscribe to whom the status of the Derby Club, and even its existence, may be quite unknown, and they may hesitate to give money for a fund about the administration of which they can have very little knowledge. With every desire to see this movement carried to a successful issue, we suggest that the Derby Club should, before going any further put the whole scheme on a broader and also a more definite business footing. The consent of well-known leaders in the wireless world to serve on a general committee should be obtained and their names announced. Trustees for the funds should be appointed, and the co-operation of eminent technical advisers as to the suitable employment of the funds should be secured. Some information should also be given as to the character of the earlier researches to be made. With a definite and responsible organisation of this kind behind them collectors would have a good case to state, and it is probable that a substantial fund would in due course accumulate. Without such guarantees of the soundness of the cause, we feel that only a very mediocre response can be hoped for, and that a well-intentioned and highly-commendable effort on the part of our friends of the Derby Club may mis-fire. The scheme is excellent in its conception; if it is to prove successful it must be equally good in its organisation and execution. There is no lack of enthusiasm in the wireless world, and we believe the public will respond if approached in the right way.

A New Feature.

Under the heading of "Experimental Problems," we commence in this issue a new feature, which should not only be of considerable interest, but of practical value to all experimenters. Readers' queries are both numerous and varied, and to find space to deal with each adequately would not be possible in EXPERIMENTAL WIRELESS without excluding considerable matter of general interest. Correspondence shows, however, that many readers experience similar difficulties, and it is these difficulties which will form the subject matter of "Experimental Problems" month by month. As our readers are aware, we do not undertake to answer queries either through the medium of this journal or through the post, but brief details of any matter which is presenting some difficulty will, if of sufficient general interest, be dealt with under the above-mentioned heading. Those who have already written to us, asking our advice on various problems, are reminded that they should look for our reply in the appropriate columns.

The Utility of Thermionic Valve Characteristics

By H. J. BARTON CHAPPLE, Wh.Sch., B.Sc. (Hons.) Lond., A.C.G.I., D.I.C.

Below are given simple methods for the determination of valve characteristics together with an explanation of the various constants and their use.

In view of the great importance of characteristic curves for all thermionic investigations and design of apparatus, the accompanying remarks on how to derive the maximum information from a given set will, no doubt, prove useful to serious experimenters.

The "static" characteristic curves of a triode (three-electrode thermionic valve) clearly indicate how the anode current changes as the grid potential is varied over a sufficient range to cause this current to rise from zero to its maximum value or *vice versa*, the anode potential being constant while the series of readings for points on one curve is being obtained. The same process is repeated for several convenient values of anode voltage, but as the details for carrying out this experiment are fairly well known, they will be omitted, but a reference to Fig. 1 will show the necessary apparatus required, and the diagram is practically self-explanatory.

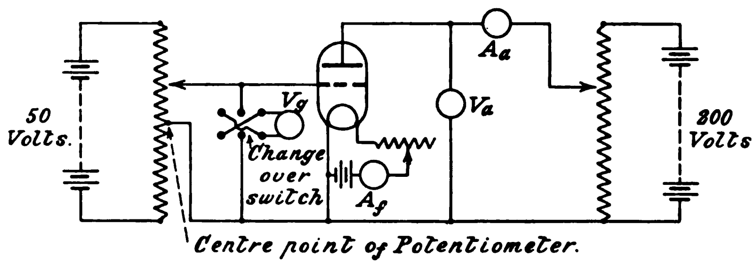


Fig. 1.—Circuit for the Determination of a Static Characteristic.

It is immediately apparent that the anode current depends upon, or is a function of, the anode and grid potentials (assuming, of course, that the filament current is kept constant), and thus the connection between the three variables can be represented by a surface in three dimensions, and this is termed the characteristic surface, while sections of this surface are known as the "static" characteristic curves, Fig. 2 being a typical set for a "hard" valve.

The most important quantities which can be derived from a given set of characteristic curves are the amplification ratio, resistance (or impedance), and the magnitude of the back E.M.F. produced by the electron current flowing from the hot cathode to the anode.

The thermionic current inside the triode consists of a stream of electrons flowing from the cathode to the anode. Since the electrons have a negative charge, they give rise to an electric field which tends to cause the electrons near the filament to return to it. This is really the "space charge effect," and can be conveniently portrayed as a back E.M.F. in opposition to the main anode battery (see "The Algebra of Ionic Valves," by Dr. Eccles, *The Electrician*, February 13, 1920). This effect can be represented in magnitude by the symbol V_s.

The amplification ratio is defined in the recent (December, 1923) publication of the British Engineering Standards Association, No. 166, as: "The numerical ratio of the slope of the anode current/grid voltage characteristic curve to the slope of the anode current/anode voltage characteristic curve of the three-electrode thermionic valve, the slope in each case being that at the point representing the particular adjustment under consideration."

When the control electrode, *i.e.*, the grid, is made positive or negative with reference

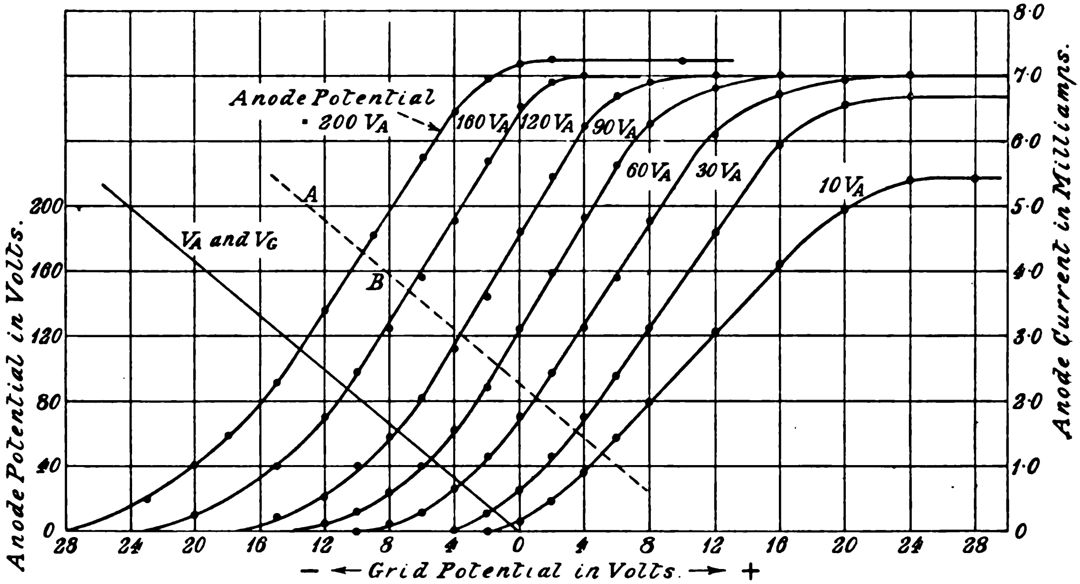


Fig. 2.—Marconi Osram Triode Anode Current-grid Potential Characteristic.

to the filament, it superimposes an electric field upon the one existing between anode and cathode, and thus alters the back E.M.F. due to the space charge. When the grid is positive, the reduction in V_s is proportional to the voltage of the control electrode, and this proportional constant is the quantity defined previously as the amplification ratio. Its symbol is μ, and for a constant filament temperature its magnitude depends mainly upon the closeness of the grid wires or mesh, and upon the relative distances of filament, grid, and anode from one another. An average value for the ordinary thermionic valve is a number between 6 and 10, and thus we see that the modification of anode voltage V_a is μV_g where V_g is the grid voltage. The importance of μ lies in the fact that it determines the value of the triode as an amplifier of feeble radio-oscillations of potential, and also for obtaining the magnitude of the reaction between the magnetically coupled grid and anode inductances when using the triode as a generator of oscillations.

The internal resistance or impedance of the thermionic valve from anode to cathode is more generally known as R_o. It is a pure resistance at low frequencies, but at high frequencies varies slightly owing to the effect of the inter-electrode capacities. This quantity also enters into all calculations connected with the design of amplifiers and "oscillators," as will be shown later in this article.

Having realised that a knowledge of these quantities is essential for the efficient use of a piece of apparatus embodying thermionic valves, it is necessary to see with what ease they can be determined from a given set of static characteristic curves.

Since the straight line portions of the curves must be used for amplification purposes, turn to Fig. 2, and choose a representative current cutting all the parallel straight portions, *i.e.*, 3.0 m.a. (milli-amperes), say. It now becomes necessary to obtain the ratio μ previously defined, and which in the appendix is shown to be the slope of the line connecting the two quantities V_a and V_g.

With a suitable anode potential (V_a) scale shown on the left of Fig. 2, we have:

When $I_a = 3{\cdot}0$ m.a. $V_g = -13{\cdot}0$ volts, and $V_a = 200$ volts.

This gives the point *A* when plotted to the chosen scales. Again:

When $I_a = 3{\cdot}0$ m.a. $V_g = -8{\cdot}5$ volts, and $V_a = 160$ volts.

This will give the point *B* when plotted, and so on, the ordinates of the points being erected vertically corresponding to the anode potentials of each curve where intersected

by the 3 m.a. line. The line joining the points *A*, *B*, etc. (shown dotted in Fig. 2), thus expresses the relation between V_a and V_g, and its slope in terms of the scales of volts, conveniently settles the magnitude of μ. (According to the usual convention, this slope is negative in the figure.) Thus we have, by taking the extreme ordinates of this line:

$$V_a = 200 \text{ volts when } V_g = -13{\cdot}0 \text{ volts.}$$
$$\text{and } V_a = 0 \text{ volts when } V_g = +10{\cdot}8 \text{ volts.}$$
$$\therefore \mu = 200/(10{\cdot}8 + 13{\cdot}0) = 200/23{\cdot}8 = 8{\cdot}4.$$

Using the same symbols for current and potential as before, the effective E.M.F. for driving the electron current is:

$$(V_a + \mu V_g - V_s)$$

Thus along the straight part of the characteristic curve the value of the anode current can be found by dividing this voltage by the internal resistance R_o, *i.e.*:

$$I_a = (V_a + \mu V_g - V_s)/R_o$$

The quantity $(V_a + \mu V_g)$ occurs frequently in thermionic valve work, so it becomes convenient to call it the "lumped" voltage (*vide* Dr. Eccles), or "total" voltage, and thus we can express this equation graphically, and call it the "total characteristic." The method for delineating this curve from Fig. 2 will now be discussed.

A full line marked V_a, V_g parallel to the original dotted line is drawn through the

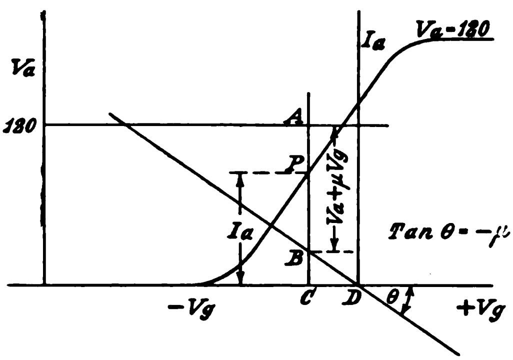


Fig. 3.—Determination of Lumped Characteristic.

origin so that its slope is obviously $-\mu$. To make the construction clear, reference must be made to Fig. 3, where the characteristic corresponding to a definite anode potential (120 volts) has been sketched with the I_a, V_a, and V_g axes shown. Drawing a horizontal line at 120 volts on the V_a scale, and choosing any point P representing I_a on the characteristic, erect a line perpendicular to the V_g axis.

Then:

$PC = I_a$. $AC = V_a$. $CD = V_g$ ($-ve$ in this case).
$\therefore BC = CD \tan \theta = -\mu V_g$
$\therefore AB = AC - BC = V_a - (-\mu V_g) + (V_a = \mu V_g)$

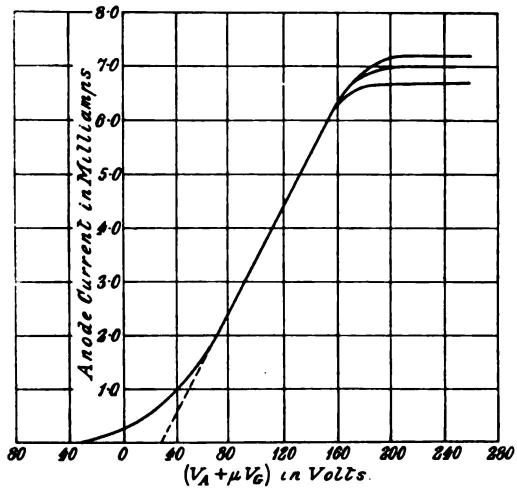


Fig. 4.—Lumped Characteristic for Triode.

Two co-ordinates for the new curve are thus easily found, and by choosing various points, P, *i.e.*, different values of I_a, a complete curve can be drawn for the definite value of V_a by transferring the lengths P,C and A,B to squared paper and plotting them so that I_a is the ordinate and $(V_a + \mu V_g)$ the abscissæ. This process should now be repeated for each individual value of V_a plotted in Fig. 2, but since it will be found that all the points for each anode potential lie approximately on the same curve, except near saturation, only one value of V_a need be taken to determine the constants V_s and R_o.

The curve shown in Fig. 4 is the new curve derived as indicated above from the set of characteristics in Fig. 2. It is now possible to determine the constants V_s and R_o for the straight portion indicated in the equation:

$$I_a = (V_a + \mu V_g - V_s)/R_o.$$

This is best done by taking two points as far apart as possible and substituting their co-ordinates I_a and $(V_a + \mu V_g)$. Expressing I_a in amperes and $(V_a + \mu V_g)$ in volts, we have from Fig. 4:

$$I_a = 0{\cdot}002 \text{ when } (V_a + \mu V_g) = 68$$
$$\therefore 0{\cdot}002 = (68 - V_s)/R_o$$

Again—

$$I_a = 0{\cdot}006 \text{ when } (V_a + \mu V_g) = 153$$
$$\therefore 0{\cdot}006 = (153 - V_s)/R_o$$

These two results can be used together and the equations solved simultaneously in the simple manner indicated:

$$0{\cdot}006 = (153 - V_s)/R_o \quad \ldots\ldots\ldots\ldots \quad (1)$$
$$0{\cdot}002 = (68 - V_s)/R_o \quad \ldots\ldots\ldots\ldots \quad (2)$$

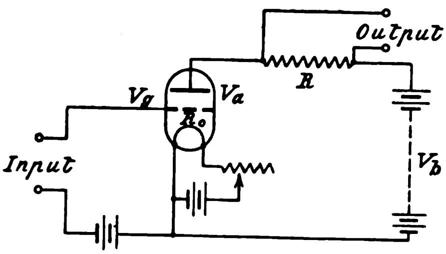


Fig. 5.—Triode Connected as an Amplifier.

Removing the brackets from equations (1) and (2) we have :—

$$0{\cdot}006 = 153/R_o - V_s/R_o \quad \ldots\ldots\ldots\ldots \quad (3)$$
$$0{\cdot}002 = 68/R_o - V_s/R_o \quad \ldots\ldots\ldots\ldots \quad (4)$$

Subtracting (4) from (3) we obtain:

$$0{\cdot}004 = 85/R_o$$
$$\therefore R_o = 85/0{\cdot}004 = 21250 \text{ ohms.}$$

Substituting this value in equation (1), we can now find V_s, *viz.*:

$$0{\cdot}006 = (153 - V_s)/21250$$
$$\therefore 127{\cdot}5 = 153 - V_s$$
$$\text{i.e., } V_s = 25{\cdot}5 \text{ volts.}$$
$$\therefore I_a = (V_a + 8{\cdot}4\, V_g - 25{\cdot}5)/21250$$

The quantities V_s and R_o can be obtained another way by producing the straight portion of the total characteristic (shown dotted) so that it cuts the $(V_a + \mu V_g)$ axis. We then have $I_a = O$ and $(V_a + \mu V_g) = 25{\cdot}5$, hence:

$$O = (25{\cdot}5 - V_s)/R_o$$
$$\text{i.e., } V_s = 25{\cdot}5$$

Again $1/R_o$ in this curve represents the slope of the line, so by finding the slope of the line and equating this to $1/R_o$ the quantity R_o becomes determinate. Thus:

$$I_a = 0{\cdot}006 \text{ when } (V_a + \mu V_g) = 153$$
$$\text{and } I_a = O \text{ when } (V_a + \mu V_g) = 25{\cdot}5$$
$$\therefore 1/R_o = 0{\cdot}006/(153 - 25{\cdot}5)$$
$$\therefore R_o = 127{\cdot}5/0{\cdot}006 = 21250.$$

Both these values correspond to those previously determined, so that either method may be adopted in practice.

The value of I_a on the straight part of the curve can now be found for any given values of V_a and V_g, or *vice versa*. Thus:

If $V_a = 160$ volts, and $V_g = -4$ volts
$\therefore \mu V_g = -33{\cdot}6$,
and $I_a = (160 - 33{\cdot}6 - 25{\cdot}5)/21250 = 0{\cdot}00475$ amps.

Again, what value of V_a will make $I_a = 3{\cdot}5$ m.a. when V_g is zero?

$$0{\cdot}0035 = (V_a - 25{\cdot}5)/21250$$
$$\therefore V_a - 25{\cdot}5 = 74{\cdot}3$$
$$\therefore V_a = 99{\cdot}8 \text{ volts.}$$

Several methods have been devised for measuring μ and R_o direct—see Appleton in *The Wireless World*, 1918, and Miller in "Proceedings of the Institute of Radio Engineers," Vol. 6, June, 1918.

It must be borne in mind that the quantities μ, V_s, and R_o have only been obtained for the straight portion of the characteristics, as this is the most important, but the fact must not be lost sight of that these three values will alter on both the top and bottom bends of the curves.

To consider two other illustrations of the importance of μ and R_o we have, for the amplifier circuit shown in Fig. 5, that the voltage amplification factor between input and output is:

$\mu R/(R + R_o)$ (For proof, see appendix.)

Thus, by assigning various values to R, it is possible to ascertain the resultant amplification factor, *viz.*:

If $R_o = 30000$ ohms, $\mu = 8$ and $R = 40000$ ohms.
Then $\mu R/(R + R_o) = 320000/70000 = 4{\cdot}6$.

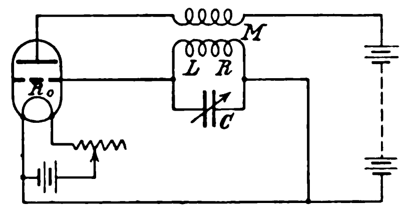


Fig. 6.—Arrangement of Triode as a Generator.

If an impedance Z had been used in place of the resistance R (*e.g.*, inter-valve transformer), then the amplification factor would have been:

$$\mu Z/(Z + R_o)$$

Again, with the triode generating circuit of Fig. 6, we have, for oscillations to be maintained, that the mutual inductance M must be negative in sign, and greater than the quantity

$(L + CRR_o)/\mu$ (See appendix for proof.)

By substituting the measured values for all these quantities, the critical value of the magnetic coupling between anode and grid coils can be easily determined.

The characteristic curve diagrams in this article were prepared from data derived experimentally in the High Frequency Laboratory at the Technical College, Bradford.

Appendix.

Using the symbols I_a, V_a and V_g, Langmuir gave the equation of the characteristic surface in the form:

$$I_a = A(V_a + k\,V_g)^{3/2} \quad \ldots\ldots\ldots\ldots \quad (1)$$

k being a constant depending upon the particular construction of the thermionic valve, grid, and anode.

It is observed that the central region of a characteristic surface is almost a plane, and the equation for that portion has been given by Vallauri as:

$$I_a = (aV_g + bV_a + c) \quad \ldots\ldots\ldots\ldots \quad (2)$$

From this we have:

$$\delta I_a/\delta V_g = a \text{ and } \delta I_a/\delta V_a = b.$$

The quantities a and b are of the dimensions of a conductance (inverse of resistance), and the ratio a/b is the same as k in (1). The internal resistance of the thermionic valve is $1/b$, and this is more generally known as R_o, as previously stated.

Van der Bijl has proposed another form of equation, *viz.*:

$$I_a = A(\gamma V_a + V_g + \epsilon)^2 \quad \ldots\ldots\ldots\ldots \quad (3)$$

$1/\gamma$ is commonly known as μ, and we have a/b, k, $1/\gamma$ or μ all representing the amplification ratio.

Since $\delta I_a/\delta V_g = a$ and $\delta I_a/\delta V_a = b$, it follows that $a/b = \mu = \delta V_a/\delta V_g$, and thus the amplification ratio is the slope of the curve formed by plotting V_a in terms of V_g. Turning to Fig. 2, we can now see how to derive this curve from the original set of plotted characteristics, by assuming the very small changes of anode current δI_a used in equations above to be equal, which is strictly correct where the characteristic curves are parallel, and choosing a representative current cutting the straight portions, as pointed out early in the article.

Thermionic Valve as Amplifier.

Referring to Fig. 5, we have:

$$I_a = (V_a + \mu V_g - V_s)/R_o$$

$$\therefore (I_a + \delta I_a) = \{V_a + \delta V_a + \mu(V_g + \delta V_g) - V_s\}/R_o$$

$$\therefore \delta I_a = (\delta V_a + \mu\delta V_g)/R_o$$

An increase of anode current causes an increased fall of potential along R, hence V_a is reduced

$$\therefore \delta V_a = -R\delta I_a$$

$$\therefore \delta I_a = (-R\delta I_a + \mu\delta V_g)/R_o$$

$$i.e.,\ \delta I_a = \mu\delta V_g/(R + R_o)$$

If V = Output voltage from terminals of R, then

$$V = R\delta I_a = \mu R\delta V_g/(R + R_o)$$

and Amplification Factor $= V/\delta V_g = \mu R/(R + R_o)$

Thermionic Valve as Generator of Oscillations.

The decrement of the oscillating circuit of Fig. 6 is easily proved to be:

$$-[R + (L + \mu M)/CR_o]/2L.$$

Thus it is plain, if the oscillations are to be maintained in magnitude, this quantity must exceed zero. This can only be accomplished when M is negative in sign, and the limiting value of M is given by:

$$M = (L + CRR_o)\mu.$$

Thermionic Valve as Rectifier.

The curve for I_a and $(V_a + \mu V_g)$ deviates considerably from a straight line below 1·5 milliamps, and it is on this portion of the characteristic that the triode is worked for rectification. Many theories have been propounded to show that the curve is parabolic for this part, and in a paper before the Wireless Section of the Institution of Electrical Engineers (March, 1922), Messrs. Moullin and Turner dealt with the theory of rectification by assuming the curved characteristic was of the form $i = f(v)$. Expanding this function in an infinite series and neglecting the fourth and higher differentials, they demonstrated that the rectified current from a very weak signal was proportional to the rate of change of slope of the characteristic, and to the square of the signal potential difference, whether the latter contained harmonics or not—a point not always noticed. By using characteristics of an "R" triode similar to Fig. 2, they proved experimentally the conclusions arrived at theoretically.

Valve Manufacture.

By W. J. JONES, B.Sc., A.M.I.E.E.

In the February issue of "Experimental Wireless" an indication was given of the methods employed in the manufacture of German valves, which contrast to some extent with British methods described below.

THE thermionic valve is assuming more and more importance as the means of detecting and amplifying wireless signals, and the experimenter can scarcely estimate the debt that is owing to Prof. J. A. Fleming for his invention of the two-electrode valve, and to Lee de Forest for the subsequent introduction of the third electrode. Readers of this journal are already conversant with the use of the three-electrode valve as an amplifier and detector of electric currents at either radio or audio frequency, but there may be a number of points in connection with the manufacture of such valves on which information is not so readily available. It is a well-known fact that the thermionic valve depends for its operation upon the emission of electrons from a heated filament which may be considered as continually emanating or evaporating these particles of negatively charged electricity in a similar manner to the evaporation from the surface of a liquid. The greater the area and temperature the more the evaporation.

Under the influence of an electric force, produced by the plate or anode potential, electrons are drawn toward the anode, and constitute a current of negative electricity flowing from the filament to plate. The third electrode, the grid, by virtue of its potential, serves the purpose of modulating the plate current, for when it is negatively charged the grid causes a decrease in the plate current, and when positive the plate current is increased.

The filament of the ordinary valve with a tungsten filament is capable of an emission of 2×10^{-13} amps. per sq. cm. at a temperature of 800° C., while at 2,500° C. the emission is increased to as much as 1·23 amps. per sq. cm. It will be noted to what an enormous extent the current rises with the temperature, and it is in order to take advantage of this improved emitting power that the filament of the ordinary valve is operated at as high a temperature as possible consistent with good life. Saul Dushman* gives the following data relating to life and temperature of tungsten filaments.

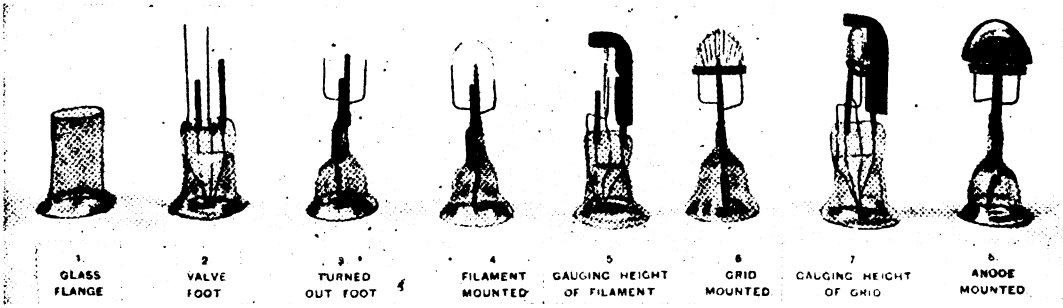


Fig. 1.—The Various Stages of Assembly of a Valve. [*Courtesy A. C. Cossor, Ltd.*

Filament Diameter. Mils.	Safe Temperature to give Life of more than 2,000 hours.
5	2475° K.
7	2500
10	2550
15	2575

(*Note.*—°K. = °C + 273.)

* S. Dushman, *G.E. Review*, Vol. 18, p. 156, 1915.

Further, the amount of emission depends largely upon the material of which the filament is composed, and the table below is obtained from work by C. J. Davisson and I. Langmuir.

Substance.	Relative Emissivities.
Oxide Coat (Western)	$3{\cdot}0 \times 10^{10}$—$8{\cdot}1 \times 10^{11}$
Tungsten	1·0
Thorium	$6{\cdot}7 \times 10^{6}$
Tantalum	5·8
Molybdenum... ...	10·8

The oxides of some materials will be seen to have very large emissivities, and that of tungsten itself is greatly improved by the introduction of thoria. It is the use of such oxides which facilitate the manufacture of low-temperature valves of such low energy consumption that they may be operated from dry batteries. The oxides of barium and strontium are usually coated on a platinum base, while the thoria is introduced into the tungsten powder from which the slug is made prior to swaging and drawing into wire.

We are only considering in these notes the construction of the bright-filament valve with a tungsten filament as is used in the manufacture of incandescent electric lamps. Langmuir has shown that the presence of

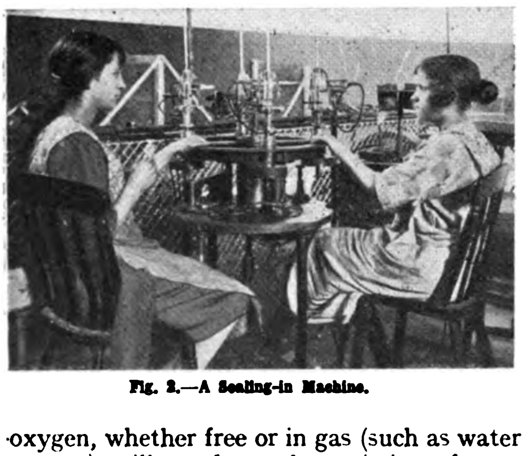


Fig. 2.—A Sealing-in Machine.

oxygen, whether free or in gas (such as water vapour), will cut down the emission of pure tungsten to a small fraction of that obtained in high vacuum. It is, therefore, of the utmost importance to ensure the attainment of really good exhaustion. To further this end, the materials of which the valve is constructed, must be carefully selected and treated, and subsequently kept as clean as possible during the manipulations necessary for the assembly of the component parts. The metal parts are heated for a prolonged

Fig. 3.—A Filament-mounting Machine.

period in vacuo at a temperature of approximately 1,200° C., after which treatment they present a bright and polished appearance. This operation extracts a large proportion of the gas which is latent within the pores of the metal, and its extraction in this way materially reduces the period of pumping. The store of gas which is found occluded by metals is so large that it will ruin the functioning of the valve altogether unless it is extracted before the valve is "sealed off."

The anodes are almost invariably made of nickel, partly because it can be obtained in great purity, and is readily worked into shape, and has a reasonably high melting point.

The grid must be rigid in order to avoid microphonic noises being produced when the valve is operating, and must not be readily melted during the process of exhaustion, when it is often rendered white hot by bombardment in order to still further drive off occluded gases. It is usually made of molybdenum wire.

The electrodes are mounted on a "foot," and it may be easier if the assembly of a particular valve is described. Fig. 1 shows the assembly of a valve in various states of completion; (*a*) shows a length of glass tube that is worked in a flame to form a flange. The flanged tubes (*b*) are placed in "foot-

making machine" and the four electrode wires threaded into position; the whole then rotates in a gas flame until the glass is sufficiently hot to be worked, when

Fig. 4.—A Group of Sealing-in Machines.

metal jaws descend upon the glass tube, flattening it and forming a pinch. It will be noticed that each of the four electrode wires is made in three sections—first the wire or the tube to which the electrode is subsequently welded, then a piece of platinum about 3 mm. long, and finally a length of copper wire, which forms the connection to

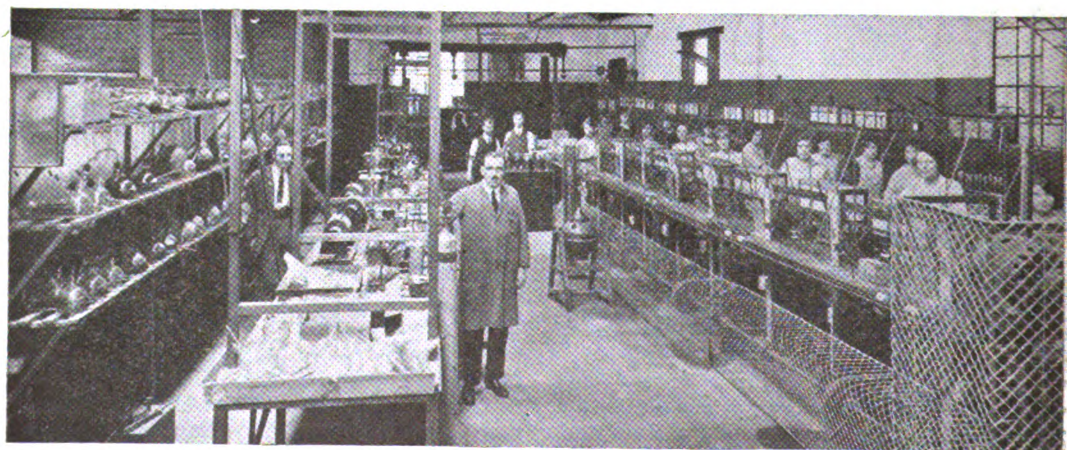


Fig. 5.—A Pumping Room in a Modern Factory.

the split pin in the cap. The glass is pinched or flattened round the pieces of platinum, as it has been found that this metal is capable of making a permanent vacuum-tight joint in the glass. The four leads shown in (*b*) are required for the following purpose:—

1. Connection to filament; (2) Tube to take grid support; (3) Connection to filament; (4) Tube to take anode.

After the wires are sealed into the glass flanges, the "feet" are kept for some hours in an annealing oven, in order to relieve the glass of any mechanical stress that may have been set up while the foot was in process of being made. Each wire in the foot is tested for electrical continuity, and passes through several operations in order to bend the

filament wires to the proper position, and to cut them off to the desired length. See (*c*). The filament consists of specially annealed tungsten wire 60×10^{-3} mm. diameter, and is automatically given its shape and measured for length. Up to this stage in the manufacture of the valve all the material and work receives careful inspection, but from now onwards still greater vigilance is kept, in particular with regard to dimensions, for it is on these that the impedance and amplification factor largely depend. In (*e*) the filament is shown being gauged for height before the grid is mounted in position. The stem attached to the grid is slipped into its supporting tube (*f*), and the grid set to its proper height by means of a gauge (*g*), being secured by welding in a high-tension electric arc in an atmosphere of hydrogen. The atmosphere of hydrogen is used in order to avoid oxidation of the metals during the heating up involved in the operation of welding.

Fig. 6.—A General View of an Assembly Room.

The finished "mounts" are now ready to be sealed in the glass bulb. The bulb, which has previously been cleaned and freed from traces of dirt and grease, together with the mount, are placed on a spindle of a machine (see Fig. 2) and rotated in a ring of high pressure gas flames until the flange of the

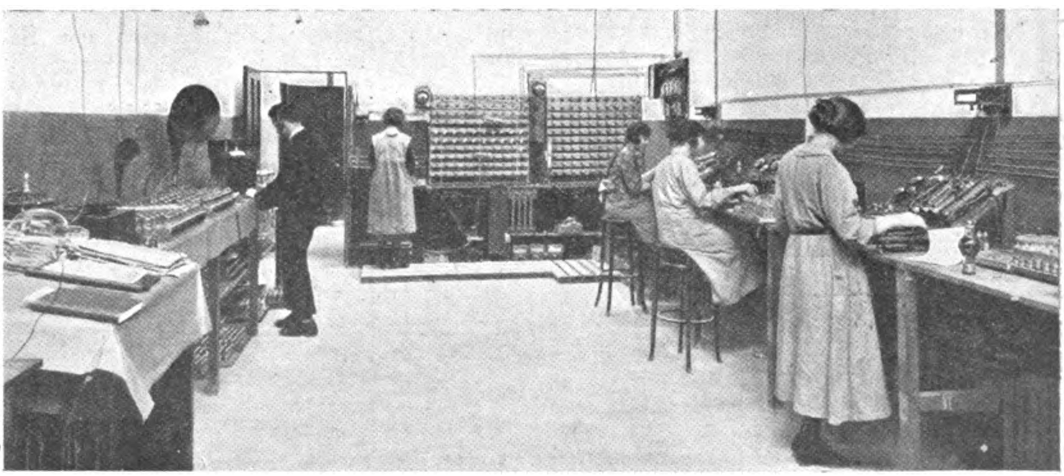


Fig. 7.—Testing Valves before Leaving the Factory

"foot" makes a perfect joint with the wall of the bulb.

The valves are now ready to be exhausted, and are placed on glass sprays connected to vacuum pumps. During pumping the filament is lighted up and high tension of several hundred volts applied to the grid and anode. When first operated in this manner the interior of the bulb appears blue, due to the ionisation of the gas present. Pumping is continued until, when the anode is red hot, due to the electron bombardment, there is no visible trace of blueing. When sufficiently evacuated the valve is sealed off and sent to the capping room, where the copper shells and four pin plugs are fitted.

All valves now pass through a period of ageing, for in the process of heating the glass in sealing-off, a small amount of gas is evolved which is absorbed when the valve is run for a prescribed time. Testing for vacuum, current consumption and characteristics then ensues, and only valves giving values within definite limits are allowed to pass, and a certain percentage are tested on actual reception and for length of life; this last enabling the manufacturer to gain some reliable estimate of the probable life of valves in a given batch. The valves are then stamped with an etching acid, essentially composed of hydrofluoric acid, and, after further final inspection, are packed ready for dispatch.

Grid Rectification.

A CRITICAL EXAMINATION OF THE METHOD.

By J. H. REYNER, A.C.G.I., B.Sc., D.I.C.

Although grid rectification is universally employed probably very few experimenters have studied its action. This is explained below and practical information is given.

THE cumulative grid method of rectification is well known, and is almost universally employed in valve circuits. As is often the case, however, with an everyday phenomenon, the underlying principles are not always fully understood, and for this reason the best results are not always obtained with this system.

It is proposed in this article to describe the method and to investigate its action in some detail, after which reference can be made to the limitations of the system.

General Theory of Action.

The best mental conception of the process is obtained by deducing the action from that of a simple amplifier (Fig. 1). Here a high-frequency oscillating voltage is applied across the grid and filament, and produces corresponding variations of the anode current

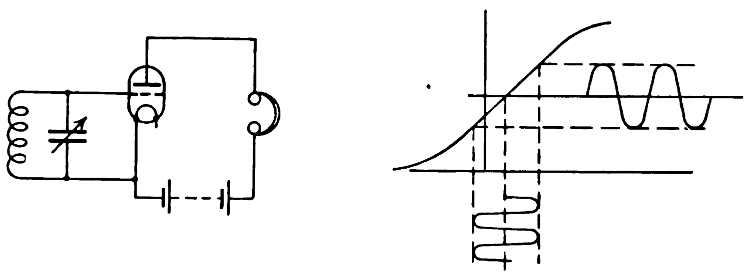


Fig. 1.—Illustrating the Action of a Valve as a Simple Amplifier.

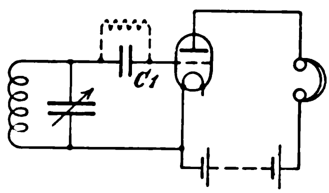
above or below the steady mean value, as indicated in Fig. 1 (*a*). Such variations, however, would not affect a telephone receiver inserted in the anode circuit, because, apart from any effect due to asymmetry of the valve characteristic, the average value of the anode current remains unchanged. This, of course, only applies to high-frequency oscillations, the telephone diaphragm being unable to follow the variations themselves, and only responding to an alteration in the mean value of the anode current.

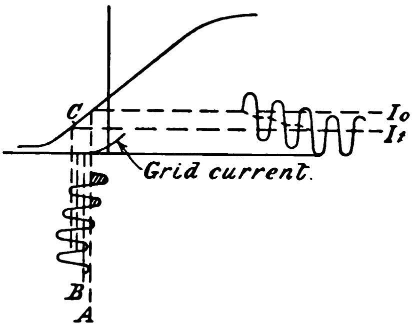
Now with this circuit when the grid is positive a small current flows from the filament to the grid and back through the external circuit. (Current is here used in the sense of an electron stream.) When the grid is negative no such current will flow.

at which point no grid current is flowing. This point occurs at different potentials with various types of valve, but the characteristic in Fig. 2 will serve for illustration purposes.

When the grid is positive a small current will flow from the filament to the grid. Due to the blocking condenser, however, this current cannot complete its circuit back to the filament, but remains as a charge on the condenser C_1. The grid, therefore, becomes slightly negative, relative to its original potential, and takes up a position as at B (Fig. 2). During the next half cycle the grid becomes more negative, but returns to the point B, since no further current has flowed into the grid condenser nor has any leaked away if the valve is hard.

The next positive half cycle will commence





Figs. 2 (a) and (b).—Illustrating the Action of a Valve as a Cumulative Rectifier.

This current will have no effect on the operation of the amplifier beyond introducing damping into the oscillating circuit L—C, which may or may not be desirable according to circumstances. In passing it may be noted that this effect will cause slight dissymmetry in the applied voltage, which will permit the oscillations to be detected faintly in a telephone even though the anode current characteristic may be perfectly straight over the working portion.

Consider now, however, Fig. 2, which is identical with Fig. 1 except that a condenser C_1 has been inserted in the grid filament circuit. The oscillating voltage applied across the points A, B is transferred through this condenser to the grid, which is thus subjected to voltage variations as before, and the anode current will fluctuate about its mean value as in the previous instance.

Now, due to the condenser in the grid circuit, the valve will adjust itself till it is working at a point A on the characteristic, from the point B, and as soon as the grid voltage reaches the point A grid current will flow and will cause an increase in the negative charge on the condenser. The negative half cycle will have no effect, as before. Each succeeding oscillation, therefore, will cause the grid to acquire an increasingly negative potential, until a point C is reached where the voltage variation never makes the grid sufficiently positive to allow any grid current to flow. The action then ceases, and the grid is left charged to a steady negative potential.

Now the more negative the grid potential the less is the anode current, other things being equal. The effect of the oscillations on the anode current, therefore, is that the variations of anode current do not take place about a steady point, but about a mean value which is decreasing in a series of jerks and finishes appreciably less than the original value.

This change is, of course, detected in the

telephones, causing the diaphragm to emit a click. Considering a spark train as the simplest type of emission, each train of waves causes a click in the telephones, and the aggregate of these impulses, occurring at a musical frequency, gives rise to a musical note. It is, of course, necessary to reset the

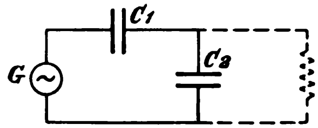


Fig. 3.—Equivalent Circuit to Fig. 2 (a).

device after each train of waves, and to effect this a high resistance is shunted across the condenser (or to the negative of the filament), which allows the charge to leak away during the comparatively long interval between successive trains of waves.

Size of Condenser.

The insertion of a grid-leak into the circuit introduces certain secondary effects, which will be considered later. The main action remains substantially as described, and it is now possible to investigate some of the points in greater detail. The first item of interest is the size of the blocking condenser. In considering this the circuit may be redrawn as shown in Fig. 3. Here G is the source of alternating voltage, C_1 is the grid condenser, and C_2 is the grid filament capacity of the valve. When the grid is positive C_2 is shunted by a high resistance (the valve having become conducting), but this effect may be neglected in the present instance, as also may the grid leak.

The voltage V will cause a current I to flow round the circuit, such that

$I = VC\omega$. C being the capacity of $C_1 + C_2$ in series.

$\omega = 2\pi f$

i.e., $I = V\omega\left(\frac{C_1C_2}{C_1+C_2}\right)$

The voltage applied to the grid is that across C_2—

$$V_g = I/C_2\omega = V\omega\left(\frac{C_1\,C_2}{C_1+C_2}\right)/C_2\omega = \frac{C_1}{C_1+C_2}\,V$$

Hence the voltage on the grid depends on the ratio of C_1 to C_2, *independent of frequency*, and to obtain best results C_1 should be large compared with C_2, so making $\frac{C_1}{C_1+C_2}$ approach unity. C_2 is of the order of 15–25 micro-microfarads, allowing for the valve-holder capacity, etc., and hence C_1 should not be lower than 200 or 300 micro-microfarads.

There is, however, a contrary effect to be considered. The value of the condenser must be such that it will build up to the full voltage required in the time available. Now the time taken to build up depends on both the capacity C and the leak resistance R where such is provided. As in all practical circuits a leak is essential these two factors must be considered together.

The full mathematical treatment is distinctly complex, because the building up depends on the grid-current characteristic of the valve, and the treatment involves both the first and the second differential co-efficients.

Fortunately, however, certain simplifications can be made in the treatment. There are two operations to be considered :—

(*a*) The building up of the condenser.

(*b*) The leak away, resetting the device for the next signal.

These operations are, of course, only distinct in the case of spark reception. For

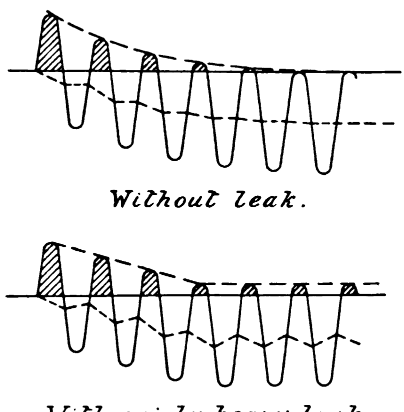


Fig. 4.—Illustrating Effect of Grid Leak.

C.W. and telephony the two operations take place together. This point, however, will be investigated later on, and for the present purpose the two operations will be considered in turn.

Time of Building Up.

During the positive half cycle the grid condenser collects a certain number of

electrons which have been attracted from the filament to the grid. The exact number, or, in other words, the actual charge, depends upon the voltage applied and the grid-current characteristic of the valve.

The voltage to which the condenser will be raised by the acquisition of this charge is given by $\frac{q}{C}$, where q=total charge and C=capacity of condenser. Obviously, therefore, the smaller the capacity C the greater the voltage acquired for a given charge.

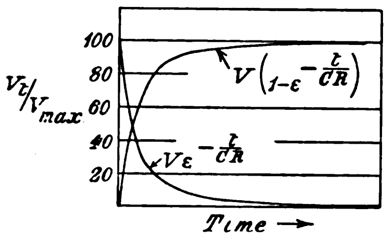


Fig. 5.—Grid Condenser Charge and Discharge Curves.

Now, as previously mentioned, the charging process continues till the steady condenser voltage is nearly equal to the maximum of the applied voltage. Hence, the greater the voltage per impulse the sooner will the condenser reach the limit. In other words, the more rapid will be the build-up. Suitable values of the capacity under different circumstances can thus be worked out. Before doing so, however, the influence of the grid leak must be considered.

Effect of Grid Leak.

During both the charging and the idle periods the voltage on the condenser is gradually leaking away. This is quite apart from the leak away after the signal has passed, in order to reset the device, and at first sight it would appear to have a serious effect on the charging of the grid condenser. Actually, however, within certain limits, the effect is very small. This somewhat remarkable point may be made clear by considering the effect in greater detail.

Fig. 4 shows the charging of the grid condenser both with and without a leak. As has been previously explained, it is only when the grid voltage rises above the point where grid current commences to flow that any charging of the condenser takes place. The effective portions of the voltage cycle are accordingly shown shaded in Fig. 4.

Without a leak, the voltage builds up rapidly at first and less quickly afterwards, gradually acquiring a steady value equal to the maximum amplitude of the applied voltage.

With a leak, on the other hand, the initial rate of building up is not so rapid, due to the leak, and the grid potential falls again during the idle half cycle from the same cause. This means, however, that in the next half-cycle the excess of the maximum applied voltage over the zero-current potential is greater; in other words, the shaded area is larger and more charge is acquired by the grid condenser. The net result is that the building up, although initially slower, continues at a more rapid rate than in the first case, and the total time required to build up is found to be very little different, whatever the value of the leak, within fairly wide limits. Mathematically it may be shown that for this condition to apply $\frac{1}{R}$ must be small compared with $\frac{1}{r}$, where r is the grid-filament resistance of the valve. r varies between 200,000 and 500,000 ohms, depending on the type of valve and position on the characteristic, which means that the grid leak cannot be reduced much below 2 megohms, which value would make $\frac{1}{R}=\frac{1}{10r}$.

It should, moreover, be noted that the final value of the grid potential is not steady, but is continually building up and leaking away, as indicated in Fig. 4. In other words, the grid voltage variations always exceed the final steady value by a small amount. This excess can be shown to be a definite proportion of the maximum voltage, and consequently increases as the applied

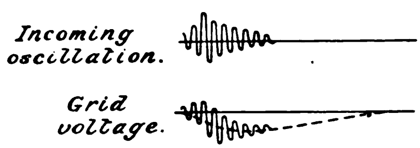


Fig. 6.—Building Up of Grid Condenser Voltage with Spark Signals.

voltage increases. This effect will be referred to later.

The building up of the condenser, therefore, is controlled almost entirely by the capacity thereof, the sole function of the grid leak being to arrange for the dissipation of the charge in good time for the next impulse.

Suitable Values of Condenser and Leak.

Now the time taken by a condenser to discharge through a resistance depends on both the capacity and the resistance. After a given time t, the voltage across the condenser is given by

$$V_t = V\epsilon^{-\frac{t}{CR}}$$

where V = initial voltage
C and R are the capacity and resistance respectively
ϵ is the base of Napierian logarithms = 2·7183

Similarly, if a condenser is charged through a resistance R, then the voltage after a time t has elapsed, will be given by

$$V_t = V\left(1-\epsilon^{-\frac{t}{CR}}\right)$$

V in this case being the applied voltage.

Fig. 5 indicates the nature of the phenomenon, and from these curves the proper sizes of C and R may be determined.

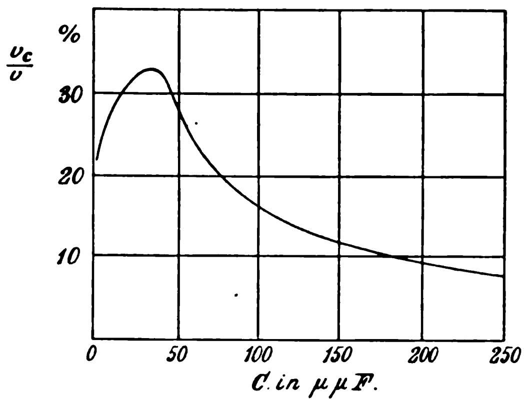


Fig. 7.—Efficiency of Rectification with Spark Signals.

The method which is adopted here is not strictly correct from a mathematical point of view, but gives a very fair approximation, which agrees with the results obtained by more complex methods.

It consists in estimating the time available for charging and then working out the value of the capacity from the formulæ given above.

The charging time is the time elapsing between the beginning of the oscillation and the point where the condenser has acquired its maximum voltage, and this is determined empirically. At first sight it would appear that the real time was only half this time, since only the positive half cycles are effective in charging the condenser. It will be seen later, however, that, due to the grid leak, there is really current flowing the whole time, but in an asymmetrical fashion, owing to curvature of the characteristic. This does not invalidate the conclusions already arrived at on the assumption that grid current only flows during the positive half cycle.

(1) Damped Waves.

Fig. 6 shows the building up of the grid voltage when receiving a spark train. It will be seen that the first three or four oscillations are sufficient to build up the voltage on the condenser, the succeeding oscillations having no effect owing to their rapidly diminishing amplitude. Consequently the time t available for building up is very small, and is dependent, moreover, on the frequency.

Assuming four effective oscillations and a wave-length of 600 metres (f=500,000) the time available is—

$$t = \frac{1}{500{,}000} \times 4 = 8 \times 10^{-6} \text{ sec.}$$

Assuming the grid filament resistance of the valve to be 300,000 ohms, which is a reasonable average value, the capacity required can be worked out in order that the voltage may build up to a given fraction of the full value during the time available. For a trial calculation the condenser will be assumed to charge up to 90 per cent. of the applied voltage.

$$v = V\left(1-\epsilon^{-\frac{t}{CR}}\right) = V(1-0{\cdot}1)$$

$$\therefore\ \epsilon^{-\frac{t}{CR}} = 0{\cdot}1.$$

$$\therefore\ \log_\epsilon \epsilon^{-\frac{t}{CR}} = \log_\epsilon 0{\cdot}1.$$

$$\therefore -\frac{t}{CR} = -2{\cdot}3026.$$

$$\therefore\ C = \frac{8 \times 10^{-6}}{2{\cdot}3 \times 300{,}000} \text{ approx.}$$

$$= 11{\cdot}6 \text{ micro-microfarads.}$$

This is, of course, ridiculously small, because the impedance of such a condenser would be so high that most of the voltage applied would be lost in voltage drop on the condenser. Moreover, such a capacity would be impracticable to work with.

In this instance, assuming the grid-filament capacity of the valve, including holder and leads, to be 25 μμF., the ratio of v_g the voltage actually applied across the grid, to the oscillating signal voltage v would be—

$$\frac{v_g}{v} = \frac{11\cdot 6}{36\cdot 6} = 0\cdot 317.$$

The voltage acquired by the condenser is only 90 per cent. of this, which gives the ratio of v_c, which is the voltage to which the grid condenser builds up, to v as—

$$\frac{v_c}{v} = \cdot 317 \times \cdot 9 = 28\cdot 5 \text{ per cent.}$$

As the value of C is increased, the build-up voltage will fall off, but the ratio of $\frac{v_g}{v}$ will increase, and the two effects tend to balance one another.

If the net ratio of $\frac{v_c}{v}$ is worked out for various values of C, the curve shown in Fig. 7 is obtained.

It will be seen that the maximum efficiency occurs around 35 μμF., but that even here the voltage acquired by the condenser is only 33 per cent. of the signal voltage, and with the values of C in common use to-day (200 to 350 μμF.) this ratio is of the order of 8 per cent. only. The method, therefore, is distinctly inefficient for spark reception, and, moreover, becomes increasingly poor the shorter the wave-length.

The size of the grid leak depends on the condenser. The time available for the leak-away to occur is very nearly 1-1,000th sec., assuming a note-frequency of 1,000 for convenience. If the condenser is assumed to lose 99 per cent. of its charge in this time, then—

$$\epsilon^{-\frac{t}{CR}} = 0\cdot 01$$

$$-\frac{t}{CR} = \log_\epsilon 0\cdot 01 = -4\cdot 6 \text{ approx.}$$

$$R = \frac{10^{-3}}{4\cdot 6\,C.}$$

If C = 35 μμF. R = 6·2 megohms.
C = 350 μμF. R = 0·62 megohm.

This last value, as has previously been shown, is too low for efficient working. It will be seen that the commonly accepted values of to-day are by no means the best as far as spark reception is concerned.

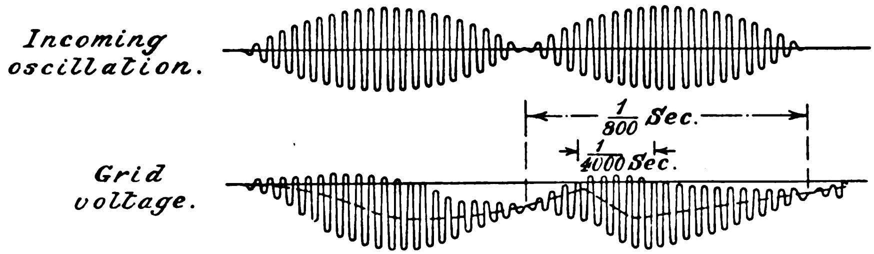


Fig. 8.—Building of Grid Condenser Voltage with Continuous Wave Signals.

(2) C.W. Reception.

The most common application of the method, however, lies in the reception of C.W. and telephony signals. The method of procedure is as before, except in one particular. With a C.W. signal the time available for charging depends on the grid leak, although in a somewhat indirect manner. Consider Fig. 8, which indicates the building-up process with a C.W. signal. It will be observed that, as the amplitude of the signal is steadily increasing for half the heterodyne modulation, the grid has a considerably longer time to build up than in the case of a spark train. Having built up, however, the charge must leak away during the remainder of the modulation, so leaving the condenser ready to build up again on the next modulation.

Now it will be found that, with the values in common use to-day, the leak away is not sufficiently rapid. Consequently, as indicated in Fig. 8, the grid does not start to

build up until the oscillations have already grown to a fairly large proportion of their maximum amplitude, and this at once limits the time available for building up. The decrease in mean grid potential is obviously somewhat reduced by this action, but it will be found that a secondary effect occurs in compensation.

From Fig. 8 it will be seen that the time available for charging is only about one-fifth of the time of one heterodyne

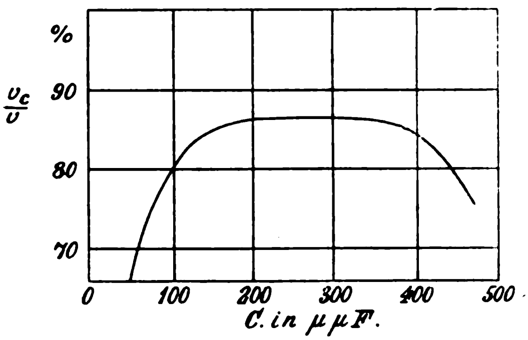


Fig. 9.—Efficiency of Rectification with C.W.

modulation. The average frequency of a heterodyne note may be taken as about 800, so that the time available is 1-4,000th second.

If, as before,

$$\epsilon^{-\frac{t}{CR}}=0{\cdot}1$$

$$C=\frac{1}{4{,}000}\cdot\frac{10^{12}}{2{\cdot}3\times300{,}000}\,\mu\mu F$$

$$=362.$$

With this value—

$$\frac{v_c}{v}=\frac{362}{362+25}=\cdot96.$$

The ratio $\frac{v_c}{v}$, therefore,

$$=\cdot96\times\cdot9=86\ \%$$

which indicates that the method is distinctly more efficient for C.W. reception. As before, a curve can be drawn showing the variations of $\frac{v_c}{v}$ as the capacity is altered, and Fig. 9 is the result.

It will be observed that this curve is really a very enlarged reproduction of the top of Fig. 7. The value of the capacity can be varied within wide limits without exercising much effect, and any value between 150 and 350 μμF. would be suitable.

The grid leak is usually made about 3 megohms. This means that in the time available, which is $\frac{4}{5}\times\frac{1}{800}$ sec. the voltage will have dropped to—

$$v=V\epsilon^{-\frac{t}{CR}}$$

$$=V\epsilon^{-\frac{10^{12}}{1{,}000\times3{,}000{,}000\times250}}$$

$$=V\epsilon^{-1{\cdot}33}$$

$$=0{\cdot}26\ V$$

assuming C to be 250 μμF., which is the maximum of Fig. 9.

This shows that the charge does not completely leak away in the time available, and hence some such action as was indicated in Fig. 8 will take place. The succeeding heterodyne modulations will thus not cause the grid to build up negative again until the amplitude has risen above the value of 0.26 volts quoted above. The maximum value to which the grid builds up is still the maximum value of the applied voltage, and consequently the effective reduction of grid voltage is only some 75 per cent. of the full voltage.

This further reduces the efficiency of the operation from 86 per cent. to 65 per cent.

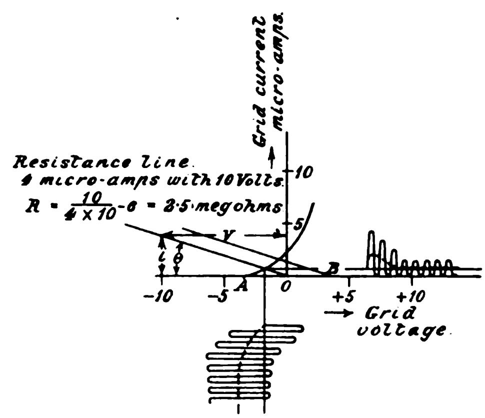


Fig. 10.—Control of Working Point by Grid Leak.

The only remedy is to reduce the leak, which, as has been seen, cannot be done, because for values below 2 or 3 megohms the leak begins to exercise an appreciable effect on the charging of the condenser. It will be seen, therefore, that the leak, though necessary, is a distinct evil.

Working Point on the Characteristic.

Owing to the presence of the grid leak, the valve does not work at the point of zero grid current, but at some other point which is determined by the value of the grid leak itself.

To elucidate this point reference may be made to Fig. 10, which shows a grid current-grid voltage characteristic. If the filament end of the leak is connected to the negative end of the filament, then a line may be drawn from O having a slope such that cot $\theta = R$ (to the same scale as the curve), where R is the resistance of the leak. At any point on this line the voltage and current will be connected by the relation $\frac{V}{I} = R = \cot\,\theta$.

Obviously, therefore, where this line intersects the grid-current characteristic will be the working point of the valve. For the grid current is determined by its characteristic and the current through the leak

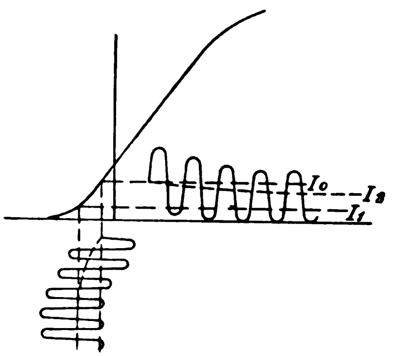


Fig. 11.—Loss of Rectification with Working Point too Low Down.

is determined by the straight line just referred to, and consequently if the two are connected together the only point fulfilling both conditions is the point of intersection.

It will be seen that the smaller the leak the steeper is the line and the farther up the characteristic is the working point. In some cases the leak is connected to the positive filament lead, in which case the leak line originates at B, which for the same value of the leak gives a working point farther up the characteristic.

Fig. 10 also indicates the true nature of the building-up process. There is a permanent grid current flowing, and the incoming oscillation causes variations of this current. Owing to the curvature of the characteristic, however, these variations are not symmetrical and there is an increase in the average grid current, which causes the condenser to build up to a negative potential. In the steady state the increase of grid current is just a little more than the decrease to make up for the loss due to leakage.

For the purpose of the general explanation of the method, however, no harm is done by assuming that the valve is working at the

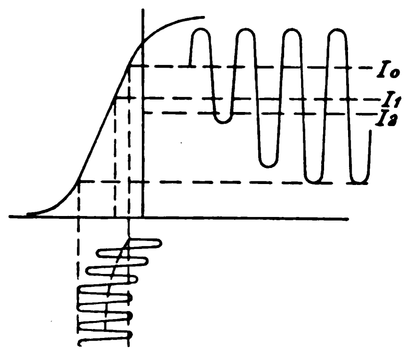


Fig. 12.—Increased Rectification at Top of Characteristic.

point A, and that the condenser is only charged during the positive half cycles, provided the true action is considered where quantitative measurements are concerned.

Telephony.

Telephony reception is similar to C.W. reception, except that for clarity of tone efficient rectification must take place with note frequencies as high as 2,000 cycles per second or more. For this purpose it is customary to use a smaller condenser (200 $\mu\mu$F. or less in place of the usual 350), which, of course, permits a more rapid build-up. It appears probable that still lower values could be employed with advantage.

The grid leak is often reduced at the same time, but since the grid leak controls the working point on the characteristic, its value depends to some extent on the type of valve with which it is employed.

Effect of Anode Voltage.

The working point on the grid characteristic is also important from its effect on the anode current.

Referring back to Fig. 2, it will be seen that the variations of anode current are perfectly symmetrical, but that owing to the grid condenser action the mean value steadily falls, finishing appreciably lower than the original value I_0.

Fig. 11, however, indicates the state of affairs when the working point on the characteristic is too low down. Here, due to the curvature of the characteristic, the variations of anode current become asymmetrical. The average value of the current is then no longer I_1, but I_2, which is not appreciably different from. I_0 In other words, the rectification effect is seriously impaired.

It will be observed that this effect is augmented by the fact that the maximum value of the grid voltage variations is always greater than the steady mean voltage to which the grid builds up. This is due to the leak, and, as has previously been mentioned, the excess voltage increases as the signal strength increases. Consequently there will be a critical value of the applied voltage at which there is no change whatever in the mean anode current, and no rectification will result.

The phenomenon occurs when the H.T. voltage is too low for the signal strength being received. A setting which is satisfactory for weak signals may be incorrect for a strong signal. This explains to some extent the limiting action on strong signals of some valve circuits, and also suggests a method of eliminating atmospherics. The remedy is to increase the H.T., while the connection of the grid leak to the positive side of the filament also obviates the trouble to some extent, because this shifts the working point well up the characteristic.

It may be remarked, in passing, that if the H.T. is increased so far that the working point occurs on the upper bend of the characteristic, as in Fig. 12, then the rectification is increased and not reduced. In this case the final value of the anode current I_2 is appreciably lower than I_1, so giving increased signal strength for the same applied voltage.

It will be obvious from the foregoing remarks that the very simplicity of the grid method of rectification is a pitfall, and a little care and consideration may result in very gratifying increase of signals. It should be observed, however, that the valve has been considered, throughout the article, as a rectifier pure and simple without any self-oscillation taking place. Such conditions introduce many secondary effects which necessitate a careful and separate study.

A Four-Electrode Valve Receiver.

By G. L. MORROW (*Development Engineer B.B.C.*)

At the presest time when many dual-amplification circuits and receivers are being disclosed the following description of a four-electrode valve receiver will, no doubt, be of great interest to the experimenter.

WITHIN the last two years much has been written, and many circuits have been disclosed with a view to obtaining what is commonly termed "dual amplification" in radio receivers. Stated briefly, the valve in a dual-amplification circuit is usually called upon to fulfil two, and in some cases three, functions. That is to say, one valve of the standard 3-electrode type may be used in a circuit in which the incoming signals are detected and then magnified at audible frequency, or the circuit may be so arranged that amplification at radio frequencies occurs as well as detection.

The object of such dual amplification is to obtain the range and signal strength of a two or even three-valve receiver with one valve, thus economising in the initial cost of the valves and in the filament watts consumed.

During the early parc of 1922 the writer spent several months experimenting with various dual-amplification circuits on short and long wave-length spark and continuous wave transmissions, and also on several tele-

phony stations. The result of these experiments tended to show that, while in some cases various dual-amplifying circuits to a certain extent accomplished what was claimed for them, the majority did not give the results anticipated. Furthermore, the circuits being of considerable complication, adjustments were tedious and unstable, and unwanted capacity effects gave much trouble. With regard to economy in first cost and maintenance, it was soon apparent that what was saved on the valves was expended to an even greater amount on the cost of the various transformers and condensers used in a dual-amplification circuit.

The writer then turned his attention to another method of obtaining dual-amplification, namely, by the use of the 4-electrode valve, and it is his intention in this article to describe a receiver of this type which has given consistently good results.

Before, however, proceeding to consider the circuit in detail, it may not be out of place to deal, very shortly, with the functioning of the 4-electrode valve.

The valve used by the writer is the 4-electrode Marconi type, which, as will be seen from Fig. 1, is not unlike the "Q" valve, but rather larger in size. The electrode system consists of a cylindrical plate, an outer grid of mesh construction

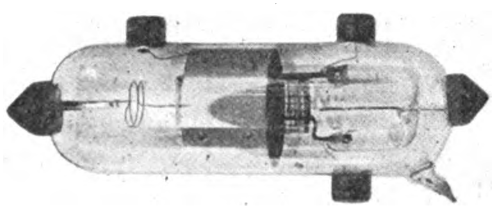


Fig. 1.—A Typical Four Electrode Valve.

and cylindrical shape, within which is an inner grid of the usual spiral form, the plate and the two grids being arranged in concentric assembly round a straight filament. The leads from these electrodes are brought to small metal caps, similar to those used in the "Q" and "V.24" types with an extra contact for the second grid. To describe clearly how this particular type of valve operates it is necessary to consider the simple application as a detector first, and then to show how it can be arranged to fulfil the functions of a high-frequency amplifier detector and note magnifier simultaneously. In passing, the writer would like to point out that where, as in the usual type of dual-amplification circuit employing the standard 3-electrode valve, it is the transformers and arrangement of the circuit

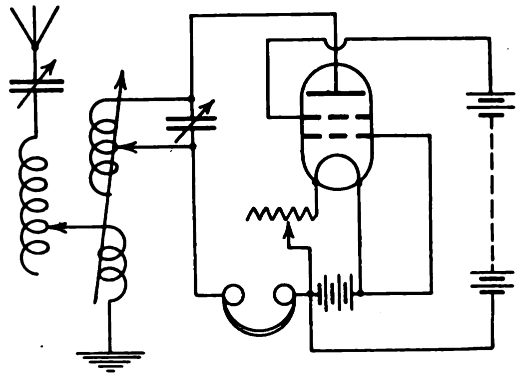


Fig. 2.—A Four-Electrode Valve used as a Detector.

which produce the desired results. In the 4-electrode valve receiver, however, the valve itself plays a much greater part in the simultaneous amplification at radio and note frequencies; in fact, the circuit which is about to be described can be built up easily by any experimenter who possesses the necessary components for a 3-valve receiver employing transformer coupled high-frequency amplification followed by a detector and one note magnifying stage.

Fig. 2 shows how the 4-electrode valve may be connected in order that it may operate as a detector, and it will be noticed that the connections of the outer grid are similar to the plate connections in a standard 3-electrode valve circuit, the high positive potential being applied to this outer grid in order that it may attract the negative electrons emitted from the filament. In point of fact this outer grid operates in a very similar manner to that of the plate in a 3-electrode valve of the usual construction, but since it has a mesh construction the electrons, emitted from the filament, will pass through this outer grid due to their velocity of emission. Now it will be seen from reference to Fig. 2 that the plate of the 4-electrode valve is connected to the

negative limb of the filament, consequently the electrons which have passed through the outer grid are repelled from the plate due to its negative potential. The inner grid, being connected to the positive limb of the filament, is maintained at a slight positive potential, and there is thus a voltage rise between the filament and the inner and outer grids which, however, is nullified by the drop in volts between the outer grid and plate owing to the negative charge on the latter. If, now, the incoming oscillations are impressed between the plate and the negative end of the filament the incoming positive half cycles will cause electrons to be attracted to the plate where the negative half-cycles will cause the plate to become more negatively charged and will be entirely suppressed. A rectified current will therefore flow in the plate circuit and will become audible in the telephones which are inserted between the low potential end of the tuning inductance and the negative end of the filament. It must not be thought that, used in this manner, the 4-electrode valve offers any advantage over the usual 3-electrode valve ; it is, as a matter of fact, less efficient, but this rectifying action has been described in order that the reader may have a clearer idea of how radio frequency amplification may be obtained in addition.

Considering Fig. 3, which shows the circuit used for obtaining both radio-frequency amplification and detection, it will be seen that the primary winding of a high-frequency transformer of the usual type is inserted in the outer grid circuit, the secondary winding being placed in the plate circuit and the incoming oscillations impressed between the inner grid and negative end of the filament.

In a similar manner to a 3-electrode valve receiver, these incoming oscillations will be magnified in the outer grid circuit and, through the operation of the high-frequency transformer coupling the outer grid and plate circuits, an alternating current will be set up across the terminals of the secondary winding.

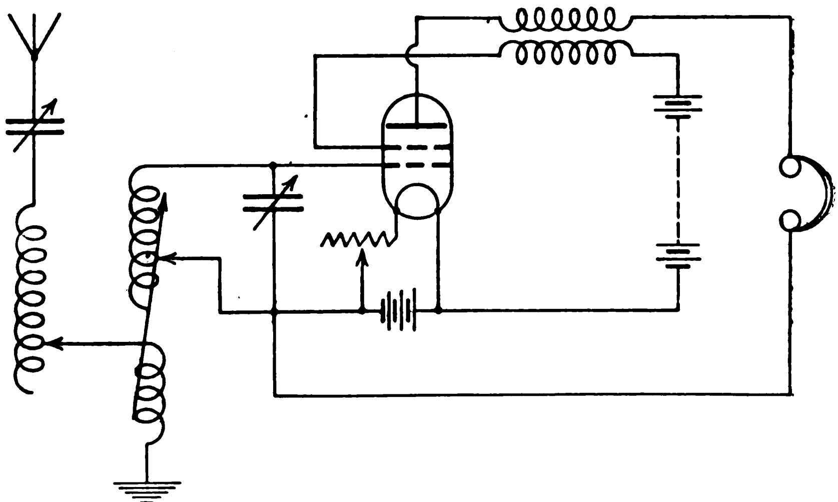


Fig. 3.—A Four-Electrode Valve used for Simultaneous H.F. Amplification and Detection.

Since the plate circuit is connected to the negative limb of the filament this alternating current will be rectified and a combined high-frequency amplifier and detector is thus obtained.

The final step is to magnify still further the low-frequency oscillations in the plate circuit by impressing these back on to the inner grid by means of a low-frequency transformer of, preferably, a one to one ratio, the note magnification being obtained in the inner grid circuit in which the telephones are placed. This circuit is shown in Fig. 4, to which has been added a power amplifying valve in order to operate a loud speaker. It would probably take the greater part of an issue of this journal to consider in

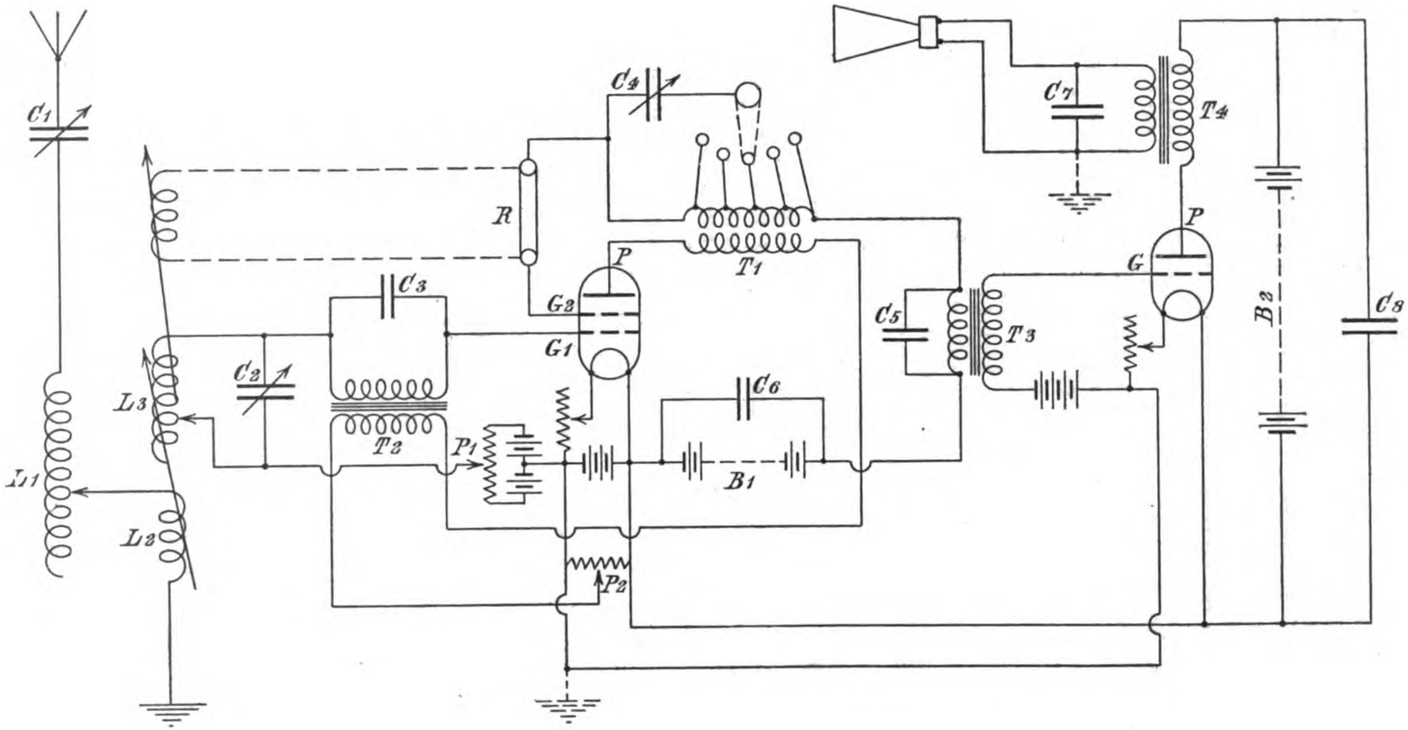


FIG. 4.—FOUR-ELECTRODE VALVE RECEIVER FOR SIMULTANEOUS HIGH-FREQUENCY AMPLIFICATION, DETECTION AND NOTE MAGNIFICATION.

L1. Aerial Tuning Inductance.
L2. Coupling Coil.
L3. Closed Circuit Inductance.
C1. Aerial Tuning Condenser, 0·001μF.
C2. Closed Circuit Condenser, 0·0005μF.
C3. By-pass Condenser, 0·003μF.
C4. H.F. Transformer Shunt Condenser, 0·0003μF.
C5. By-pass Condenser, 0·005μF.
C6. H.T. By-pass Condenser, 2μF.
C7. Telephone Condenser, 0·25μF.
C8. H.T. By-pass Condenser, 2μF.
T1. Radio-frequency Transformer.
T2. Low-frequency Transformer, 1/1.
T3. Note-magnifying Transformer, 4/1.
T4. Telephone Transformer.
B1. 30-50 Volts.
B2. 150-350 Volts.
R. Reaction Link.
P1. Inner Grid Potentiometer, 250 ohms.
P2. Plate Potentiometer, 250 ohms.

detail the action of the 4-electrode valve, but it is hoped that the foregoing rather brief description may be sufficient for the reader to grasp the outline of the main functions of this most interesting receiver. Before passing on to describe the values of the various components of the circuit shown in Fig. 4 the writer would mention that this receiver, on a standard Post Office aerial of a mean effective height of 25 ft., located 30 miles N.W. of London, gives good loud-speaker signals from the Birmingham, Cardiff and Manchester stations of the

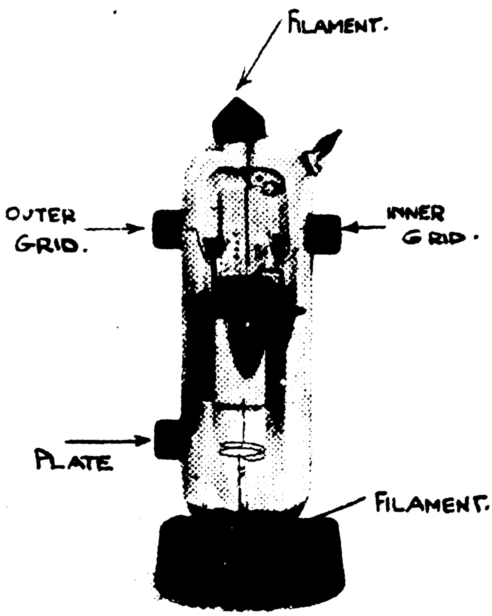


Fig. 5.—Showing the Relative Positions of the Electrode Connections.

British Broadcasting Company, 2LO works the loud speaker to the maximum of its capacity, and all the remaining stations of the B.B.C. give loud reception in the telephones.

Paris, Radiola, and the R.A.F. telephony station in Jersey give practically the same volume in the loud speaker as Birmingham. Considering the circuit (Fig. 4) in detail, the aerial tuning condenser, inductance and coupling coil, together with the secondary inductance and condenser may be of the usual type employing cylindrical inductances or duolateral coils may be used if desired. The note magnifying transformer (T2) should be, for preference, of a one to one ratio, and be shunted by a condenser of 0.003F capacity to by-pass the incoming oscillations, in their inital stage, on to the inner grid. The writer uses the 6,000 and 12,000 ohms windings of a Marconi "Universal" transformer (which may be obtained quite cheaply from most dealers in ex-Government apparatus) with the 12,000 ohms winding in the inner grid circuit. The potentiometer (P1) is of 250 ohms resistance, and, while not essential, gives a very useful control of the inner grid characteristic.

It will be seen that the plate circuit is connected through the secondary winding of the high-frequency transformer (T1) and one winding of the low-frequency transformer to another potentiometer (P2)—also of 250 ohms resistance. This potentiometer enables the plate potential to be varied, and will be found in practice to prove of the utmost help in eliminating jamming.

The high-frequency transformer (T1) mentioned above, may be of the usual type with tappings on the primary, a further refinement being the variable condenser (C4) of 0.0003F. capacity in shunt for fine tuning. If desired, a small reaction coil may be connected across the terminals (R) in the outer grid circuit, and when used will be found to bring up the signal strength at least 25 per cent., besides enabling the receiver to be used for the reception of C.W. signals.

The high-tension battery (B1) which should not exceed 50 volts is shunted by a Mansbridge condenser (C6) of 2μF capacity, and the note magnifying transformer (T3) has its primary winding shunted by a condenser (C5) having a capacity of 0.0005 μF. In conclusion, the writer does not lay claim to any originality in the circuit, as, with the exception of the addition of reaction and the use of a power amplifier in place of the telephones, it is essentially the same as that employed in marine 4-electrode receivers.

It is hoped, however, that the use of this receiver for amateur work may prove of interest and open out a very interesting field for experiments to those who wish an entirely satisfactory and efficient form of dual-amplification.

Supersonic Heterodyne Receiver Employing a Four-Electrode Valve.

By A. L. WILLIAMS, R.N. (ret.).

Below will be found details of a super heterodyne receiver employing a four-electrode valve which operates on the modulation principle.

ALTHOUGH for most practical purposes a well-designed and constructed two or three-valve receiver is all that the average experimenter requires, there is undoubtedly a demand for a receiver that will give real volume to a very distant signal, and, with this, a high degree of selectivity.

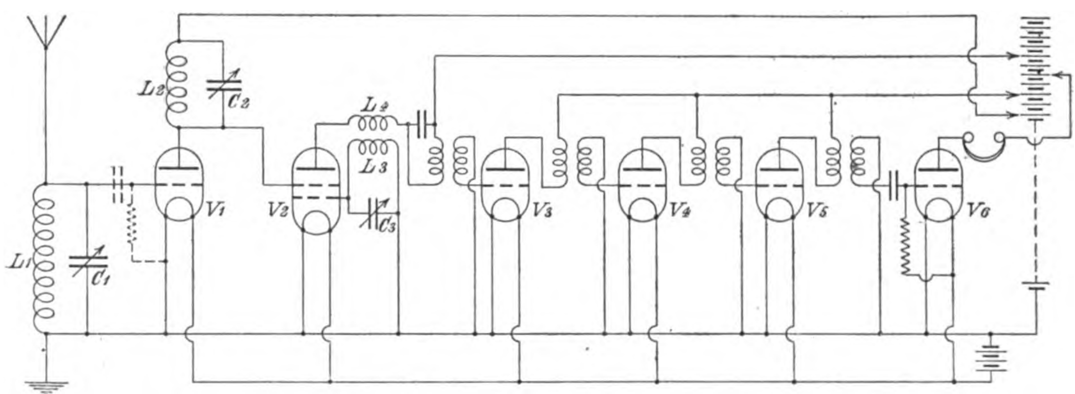


Fig. 1.—A Six-valve Super-heterodyne Receiver Employing a Four-Electrode Valve.

On the wave-lengths with which we are chiefly interested, say, between 80 and 500 metres, I do not think that more than one stage of high-frequency amplification is really practicable; firstly, because of the time taken to tune more than three critical circuits; secondly, that which always haunts us (or should) on the shorter wave-lengths, unwanted capacity effects. For these reasons I suggest the following circuit for giving both excellent results and wide scope for experimenting, and also, when constructed, being surprisingly easy to handle.

The receiver operates on the "modulation" principle, *i.e.*, the incoming signal is caused to modulate the output of an oscillating valve, so as to give a combined frequency equivalent to, say, 4,000 metres, which may then go through three or four stages of amplification at that wave-length, and is finally rectified. It will be seen, therefore, that it differs somewhat from the more usual form of supersonic heterodyne, and gives greater amplification for an equal number of valves. Another point of interest in this circuit is that it makes use of a "four-electrode" valve, that is, a valve with two grids.

In Fig. 1 V1 is an ordinary valve, preferably of small self-capacity, such as the V.24 Ora "B," coupled to the aerial in the manner and with its anode circuit "tuned." The anode is also connected direct to one grid of V2, a "four electrode" valve. The second grid of this valve is also "tuned," and is inductively coupled to its own anode circuit. H.T. is supplied to this valve through the primary of a high-frequency transformer, which with a by-pass condenser of about .0003 μF. tunes to say 4,000 metres. The secondary of this transformer supplies the grid of the first 4,000 metre high-frequency amplifier V3. I suggest that this is followed by at least two more high-

frequency stages to the rectifying valve V6. In the sketch I have shown transformers, but choke or resistance-capacity coupling may be used for the latter stages.

As this circuit is inherently very selective I have not found it necessary to use a loose-coupled aerial circuit, but for work below, say, 200 metres an aperiodic aerial closely-coupled to the tuned secondary has been found very useful, without increasing the number of adjustments necessary to bring in a signal.

The *modus operandi* of this circuit is as follows :—

Valve V2 is caused to generate oscillations at a frequency of say 1,075,000 by means of the coupling between its anode and second grid, the frequency of which is controlled by the grid circuit L_3C_3. An incoming signal on a wave-length of, say, 300 metres (or a frequency of 1,000,000 cycles) is amplified by V1, and impressed on the first grid of V2, thus "modulating" the output of V2. This valve will then be emitting, amongst others, oscillations at a frequency of 1,075,000 − 1,000,000 or 75,000, which alone are passed on *via* the first high-frequency transformer to V3. It may be mentioned here that if V2 is oscillating at a frequency of 925,000 cycles the result will be the same (*i.e.*, there will still be a 4,000-metre component). There are, therefore, two positions of C_3 which will bring in the signal.

A potentiometer should be used to control the grids of valves V3, V4 and V5, one of which may be allowed to oscillate for the reception of C.W. signals. It is also very important that the correct potentials should be applied to the two grids of V2—these can only be found by trial. For the sake of simplicity and to allow for the various arrangements possible, rheostats and potentiometers are not shown in the sketches.

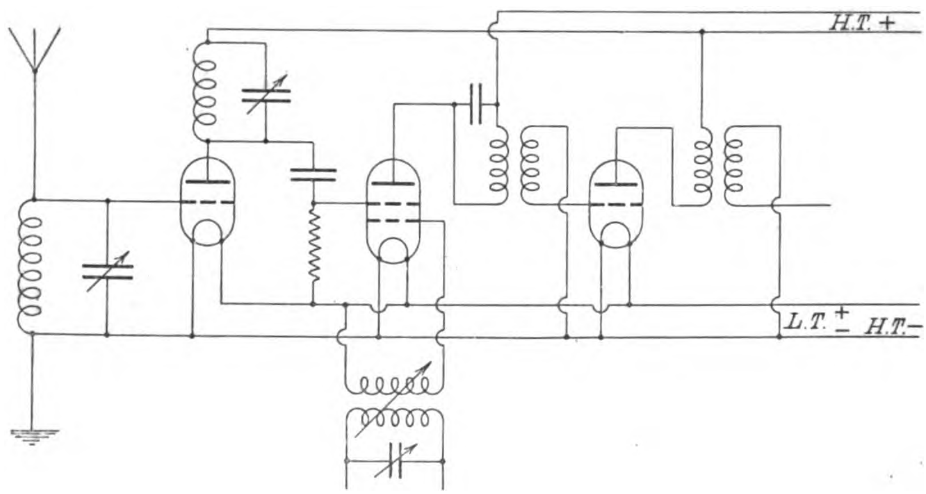


Fig. 2.—A Modification of the Circuit Employing a Local Oscillator.

Fig. 2 shows a circuit on the more usual principle, making use of a separate oscillator; but still taking advantage of the "four-electrode" valve. This circuit may be preferred by those who already possess a heterodyne wavemeter, or, alternatively, the extra valve may be "built-into" the set.

The action of this circuit is similar to the usual supersonic-heterodyne, except that the incoming and local oscillations are "combined" in a "four-electrode" valve, with, I find, a considerable gain in efficiency.

The Heartshape.

BY F. YOULE, B.Sc., A.C.G.I.

Experimenters who are anxious to receive some particular transmission with the minimum of interference will find that the heartshape method is one of the best solutions.

THE heartshape method of reception is used when it is necessary to obtain the sense as well as the direction of the transmitting station. It is also of great use in eliminating interference, as the receiving power is limited greatly in direction. Thus it is possible to separate stations on the same wave-length if they are on opposite sides of the receiving aerials. The frame aerial can determine direction, or separate stations whose bearings are 90 degrees apart, but it has two maximum points, while the heartshape has one only.

The simple vertical aerial has a circular diagram of reception, as its receiving or transmitting power is the same in all directions, in a horizontal plane. This is graphically represented by drawing a circle whose centre denotes the position of the aerial, and the radius is a measure of the radiating or receiving power.

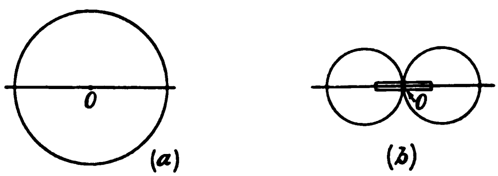


Fig. 1.—Reception Diagram for a Horizontal and Frame Aerial Respectively.

The frame aerial has a figure 8 diagram, the maximum receiving power being in the plane of the frame, and the minimum in a plane at right angles to it. The point o (Fig. 1*b*), represents the position of the vertical axis of the frame, and the proportional receiving power in any given direction is obtained by drawing a chord from o in that direction, and measuring its length. The selectivity is obviously greater than that of the vertical aerial, but stations on approximately the same line cannot be separated owing to the double maximum. This often renders a frame useless on the coast. If one were trying to receive London at Brighton on a frame, any ship or station in the channel or in France on the Greenwich meridian or thereabouts will come in, so that the selectivity is to a certain extent useless.

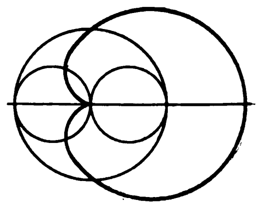


Fig. 2.—The Combination of Horizontal and Frame Aerial.

The heartshape will enable one to eliminate such interference almost completely. The diagram in Fig. 2 illustrates the receiving powers of the combination, and it will be seen that it is made up of the two diagrams already mentioned. In practice the two aerials are used, and the currents in both are combined by means of suitable couplings to the receiving amplifier circuit. The mechanism of this combination is extremely interesting, but before it can be understood a knowledge is essential of how vertical and frame aerials receive.

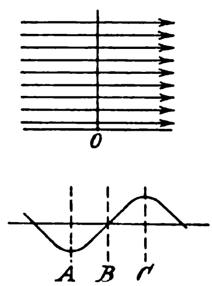


Fig. 3.—Reception on a Horizontal Aerial.

Let us take firstly the vertical aerial. The magnetic field produced at the point o (Fig. 3) by a station which is in a direction

vertical to the plane of the paper at that point may be represented at a given instant by the lines of force shown. As these cut the aerial they will produce an E.M.F. in it which will be proportional to the field

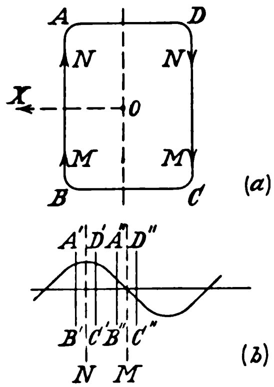


Fig. 4.—Reception with a Frame.

strength. If the latter varies sinusoidally the E.M.F. strength will be represented by a sine wave in phase with the field, assuming the aerial to be correctly tuned, and *the current will be in phase with the field.*

Turning to Fig. 4*a*, the transmitting station is in the direction OX. The magnetic field, which is perpendicular to the plane of the paper, on cutting AD and BC produces simultaneously equal and opposing E.M.F.'s in them, as indicated by the arrows. These therefore cancel out at every instant. In

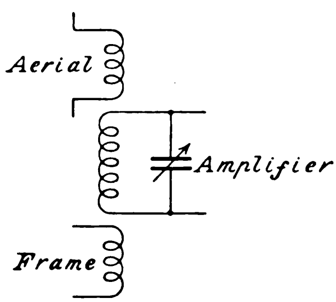


Fig. 5.—Reception with Combined Horizontal and Frame Aerials.

AB and DC there will be E.M.F.'s which do not cancel, except at one instant. A consideration of Fig. 4*b* will make this clear. The sine wave represents the field strength at any particular instant between two places a wave-length apart. Let the axis of the frame be at the point N, and its vertical sides be A′B′ and D′C′. The field strength is a maximum at N, and is slightly less at A′B′ and D′C′, producing equal E.M.F.'s NN (Fig. 4*a*) which cancel. Thus when the field at the axis of the frame is a maximum the E.M.F. round the frame is zero. Suppose now that the frame is at M. The field strength at the axis of the frame is zero. At A″B″ and D″C″ the two small field strengths are equal, but of opposite sign, and produce the E.M.F.'s MM (Fig. 4*a*). These add and give a resultant round the frame. It is easily seen that this resultant is a maximum at this point, increasing sinusoidally from the zero at N. The E.M.F. in a frame is thus 90 degrees out of phase with the field, and if it is tuned the resulting *current will also be in quadrature with the field.* It is also seen why the signals received on a frame are so much weaker than those received on a vertical aerial of average size. Not only do many less lines

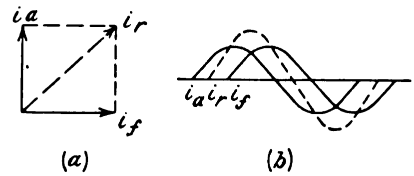


Fig. 6.—Illustrating the Conditions for Fig. 5.

of force cut the vertical sides, because they are so much shorter than the vertical aerial, but the two E.M.F.'s in these arms are nearly equal and the resultant depends on their difference, which is of necessity very small.

Suppose now that we are receiving a station on the two aerials, and we couple both to an amplifier circuit as indicated in Fig. 5, adjusting the couplings so that the two E.M.F.'s set up in this circuit are equal. The currents, if all three circuits are tuned correctly to the wave-length of the signals, will be 90 degrees out of phase (Fig. 6), and the resultant current will be of the form shown in dotted line. The vector diagram for this is given in Fig. 6*a*.

If the aerial is very slightly mistuned the current will no longer be in phase with the E.M.F. Let us mistune so that it leads or lags 45 degrees, and then mistune the frame so that its current will respectively lag or lead by the same amount on its E.M.F. Then the two currents may be either in

phase or 180 degrees out of phase, and their effects in the amplifier circuit will then be to produce in the first case signals of double the strength of either alone, the coupling being as before; and in the second case the E.M.F.'s will cancel and no signals will be heard. (Figs. 7, *a* and *b*.)

Applying this to Fig. 8, the station A′ will produce at o the E.M.F.'s E_a and E_f, respectively in the aerial and frame. These being correctly mistuned and coupled in the right proportions to the amplifier circuit, as explained above, will produce the equal currents I_a and I_f, let us say, in that circuit. If station A″ is transmitting on the same wave-length, producing an E.M.F. E_a in the vertical aerial, it is easily seen that in the frame the result is not also E_f, but E'_f.

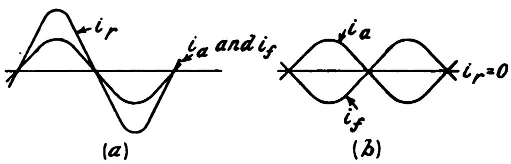


Fig. 7.—The Effect of Introducing a Lag of 45° in both Aerials.

Referring to Fig. 9, the field due to A′ is passing through the zero point and increasing. The E.M.F. in AB is negative and that in DC is positive, the resultant being a clockwise one. That due to A″ is also passing through the zero point and increasing. The E.M.F. in AB is positive and in DC negative, the resultant being anti-clockwise. In both cases the E.M.F. in the vertical aerial would be zero, and increasing, but in the frame we have two maxima of opposite sign.

Going back to Fig. 8, if the current produced by E_f is I_f, the current due to E'_f must be I'_f, which is 180 degrees out of phase with I_a. As the difference of signal strength in the aerial and the frame is compensated for by the coupling adjustment, I_a is equal to I_f and I'_f, hence the latter in effect wipes out I_a. Actually, of course, no current flows at all.

Thus, though both stations are on the same wave-length, and neither the aerial or the frame alone would separate them, the combination will do so. By reversing the coupling of the frame, or rotating it through

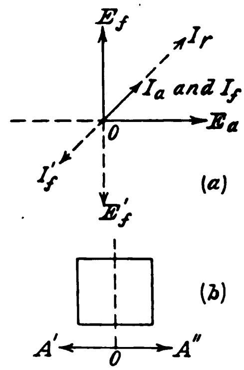


Fig. 8.—The Effect of the System on two Stations A′ and A″.

180 degrees, either station may be selected, to the exclusion of the other.

It may now be understood how the heart-shape diagram is obtained. If the large circle is taken as positive, representing the vertical aerial reception, the frame is rotated so as to make the small circle on the side of the station desired positive, the other being negative. On adding the two diagrams the heartshape results. When the frame is reversed the signs of the small circles are reversed and the heartshape swings round with the frame.

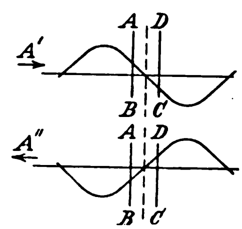


Fig. 9.—Illustrating the Conditions of Fig. 8.

Although it appears that stations in quadrature should be separated more completely by the frame alone, it does not always work out in practice, the combination seeming to be quite as good.

The Problem of High-Tension Supply.

INTRODUCTION.—1.

By R. MINES, B.Sc.

So many queries have been received relating to the supply of high tension that we have arranged for a short series of articles on the subject. The articles will summarise the various methods available, giving practical information, and should prove of considerable value to those interested in transmission.

It may be stated that the large development in the radio world since pre-war days is in a great measure traceable to the advent of the triode valve. In commercial transmission of radio messages the Poulsen arc is playing a part comparable in importance to that of the valve, but for reception purposes the valve is almost without competitor. This almost universal use of the valve for reception and transmission, too, has brought the radio worker face to face with important secondary problems.

Any relay, or amplifier, or converter, whether embodying a valve or not, requires for its working at least one auxiliary source of electrical power, in addition to the controlling source. The three-electrode valve in its present form, with an electrically-heated filament, is no exception, for it requires at least two such auxiliary supplies. The most obvious of these is the supply of current for heating the filament. This presents no difficult problem from the technical point of view, though the development of the valve in the direction of economising on current requirements is a fascinating subject in itself. The recent article on "Dull Emitter Valves" in the November issue of EXPERIMENTAL WIRELESS was a valuable contribution to the subject.

The second supply required by the valve is the power supply to the anode or plate, and we intend to deal with this problem here, for it is at once the most important and the most difficult. It is the most important, because, whether a valve is functioning as amplifier or as oscillator, it is the anode supply which constitutes the local source that is controlled (modulated) or converted into oscillatory power, as the case may be. It is the most difficult, because, although the current supply to the anode is comparatively small, it must be maintained under an electric pressure which is at once of considerable magnitude and extremely constant in value. There have been developed recently some special receiving circuits which function correctly when only a low-tension source (up to 10 volts, say) is used as anode supply; in general, however, the lowest value used in this country is about 50 volts. (It may be noted here that 25 volts is a common figure for American practice, and for use with "soft" valves, but this need not affect our problem to any considerable extent). This minimum value is quickly exceeded in amplification work, where the pressure may be measured in hundreds of volts, and in transmission work, where the pressure may be measured in kilovolts.

We now have a concrete idea of what the requirements are in the matter of values of anode pressure used in radio work. The problem that arises for solution is, how are these requirements to be met. Naturally, the choice of a solution depends not only on the particular function the valves supplied are required to fulfil, it is affected also by the conditions of working, *i.e.*, what facilities are available in the way of electricity supply and what apparatus the radio worker is able to allocate to the purpose of high-tension supply. It may be assumed that a large number of the readers of this journal have to "start from the beginning," *i.e.*, have no suitable electricity supply, and, what is more important, will in any case have to purchase for the purpose any electrical apparatus required to deliver the desired high-tension power. The needs of readers will, therefore, best be met by a complete survey of the subject to cover all cases.

The various systems that may be employed for obtaining a high-tension supply may, in

the first instance, therefore, be classified into three groups:

I.—Suitable for workers having an *A.C. supply.*

II.—Suitable for workers having a *D.C. supply.*

III.—Suitable for workers having *no electricity supply.*

It will be shown, however, as the various methods are detailed below, that the best method for any radio worker to utilise, bearing in mind his particular requirements, may fall outside the category indicated by the facilities available.

Following is a brief survey of the methods available at the present day, grouped under the categories given above. Each method is allocated to that group which means the most direct utilisation of any electric power available.

I.—(1) When an A.C. supply is available, and its pressure bears the correct ratio to that required, it may be converted direct into the required D.C. supply by means of some form of *Rectifier*, followed by a smoothing apparatus or *Filter*.

(2) When the A.C. supply pressure is different from that of case (1) it may be stepped either up or down, through very considerable ratios; by means of a *Transformer*. Subsequently the supply is sent through a rectifier and filter as in case (1).

II.—(1) When a D.C. supply is available whose pressure is in excess of that required for the radio work, a fraction of the pressure is most simply obtained by means of a *Potential Divider*.

(2) Obviously if the supply pressure be equal to that required, *direct connection* may be used.

(3) Should the supply pressure be insufficient, it may be stepped up by means of an *Electrostatic Transformer* (consisting of condensers in series charged successively from the supply of a high-speed commutator).

Both cases (1) and (3) admit of the use of a motor generator or a rotary transformer.

In each case it will be necessary to use a filter apparatus.

III.—When no electricity supply is available there is obviously no alternative but to generate the required electric power. Here will be considered the direct generation of the high-tension supply, though it is sometimes better to generate a lower tension D.C., or, more usually, an A.C. supply, and subject this to conversion, etc., as described above.

(1) The *Primary Battery* and the *Secondary Battery* take their place here, for they are really "chemical generators."

(2) The *Wimshurst Machine* should be mentioned as representing the electrostatic generators, though its sphere of usefulness does not cover ordinary radio work.

(3) The Electro-magnetic Machine, or *Dynamo*, is well represented in radio practice. These machines may be further classified according to the type of drive employed:

(i) With mechanical drive (by hand, treadle, or prime-mover);

(ii) with separate electric motor (giving a "motor generator");

(iii) with driving motor built as one with the generator (giving a "rotary transformer");

Note that in case (ii), and similarly in case (iii), the driving power may be obtained from electricity supply mains, either A.C. or D.C.

(4) There is also the Impulse Generator, represented by the *H.T. Magneto* and the *Induction Coil* (though this is really a converter or transformer rather than a generator.

These machines obviously must be used with a smoothing device (filter), and a rectifier or a minimum-potential device is also necessary.

Rectifiers.—There are a number of practicable method of rectification that may be used with alternating and impulsive supplies, as detailed below:

(1) *Mechanical* (commutator or distributor);
(2) *Electrolytic* or chemical.
(3) *Air-Blast* (assymmetric arc);
(4) *Ionic* ("gas discharge" vacuum devices);
(5) *Electronic* ("hard" vacuum tubes, with hot cathodes).

It is proposed to devote further articles to detailed descriptions of the above methods of High-Tension Supply and Rectification and a discussion of their relative advantages and disadvantages in relation to both the radio service required and the conditions and costs that have to be faced in installing the supply.

(To be continued.)

The Effect of the Series Condenser in a Transmitting Aerial.

By E. H. ROBINSON.

At first sight it would appear that, given an aerial system of fixed dimensions with a certain H.F. current flowing in it, the energy radiated into the ether would be quite a definite quantity whatever circuits were used to obtain this aerial current. It might be argued that compared with the electric field between aerial and counterpoise (or earth) the field due to the apparatus in the operating room is negligible

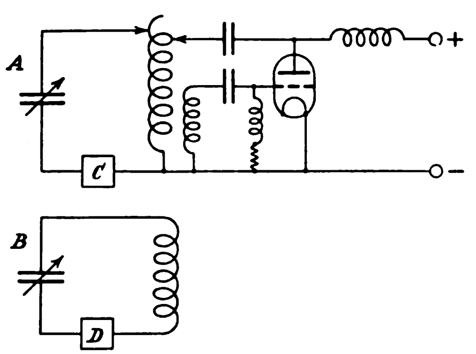


Fig. 1.—The closed circuit B is excited by the valve oscillator A. The oscillatory current in the circuit B may exceed that in A, even though similar condensers and inductances are used in both circuits.

and therefore why worry what happens in the operating room as long as the desired H.F. currents are going into the aerial and counterpoise leads on the right wave-length ? This reasoning is right up to a certain point but there are some other effects which may play an important part—especially when a condenser is used in series with the aerial inductance for the purpose of operating the set at a low wave-length. As far as tuning the aerial to any desired wave-length is concerned it makes very little difference whether the condenser is inserted above or below the inductance, but where damping, losses and distribution of the aerial field are concerned the position of the series condenser may make a great deal of difference. It is the object of this article to consider in an elementary manner the effect of a series condenser on the aerial losses and on the distribution of the radiated field.

Losses due to Loading or Earthing Anti-nodal Points of an Oscillatory Circuit.

Loss-hunting in transmitting circuits is an interesting and instructive pastime. The following simple experiment made by the writer emphasised the importance of the correct arrangement of circuits to avoid loading any but the potential nodes of a circuit. A conventional type of valve oscillator was set up as shown at A in Fig. 1 and an entirely isolated resonant circuit B was fairly loosely coupled to it. The oscillatory currents in each circuit could be read on instruments inserted at C and D respectively. The filament end of the inductance in A is shown earthed as the filament battery and H.T. supply have a capacity to earth even if no intention of earth connection were provided. The circuit A was first adjusted to give the maximum reading on the thermo-ammeter C (circuit B being temporarily removed). This reading was very discouraging as the current registered was well under an ampere although the input to the valve was several watts. No matter what adjustments were made to the anode tap or grid coupling this current could not be materially improved for a given power input. Losses were therefore indicated of greater magnitude than could be accounted for by condenser and inductance losses. Circuit B was then loosely coupled to A and carefully tuned to it. Resonance was very sharp and much larger currents were registered in the circuit B than could be obtained in the original circuit A. This was very puzzling at first, especially as the actual condensers, inductances and meters in A and B respectively could be interchanged without affecting the result. Throughout the experiment the condensers in A and B were kept approximately equal in capacity.

The next step was to try the effect of

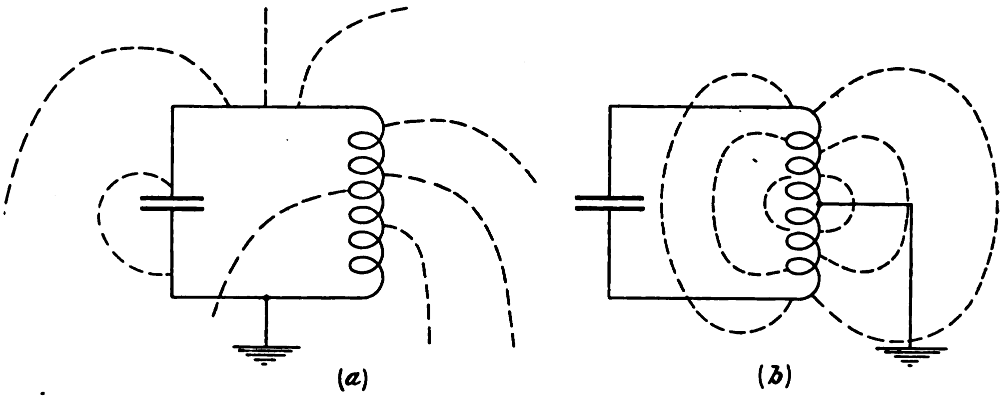


Fig. 2.—Showing how the location of the nodal point in an oscillatory circuit may affect the distribution of the electrostatic field of the circuit.

earthing different points in the circuit B. An earth wire was connected to one extremity of the inductance in B and the reading on D immediately dropped a full 50 per cent., and no amount of retuning would restore the current to its initial value. The earth wire was then touched on various turns of the inductance, a point being found somewhere in the middle of the inductance which could be earthed without reducing the

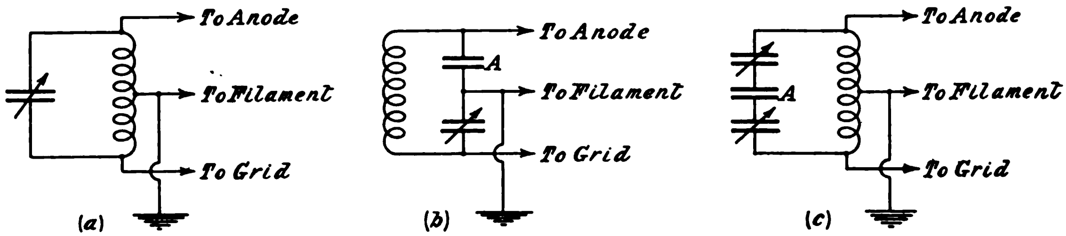


Fig. 3.—Three types of circuit in which node is naturally located at filament and earth tap. (a) Closed Hartley Circuit ; (b) Colpitt's Circuit ; (c) Reinartz modification of Hartley Circuit.

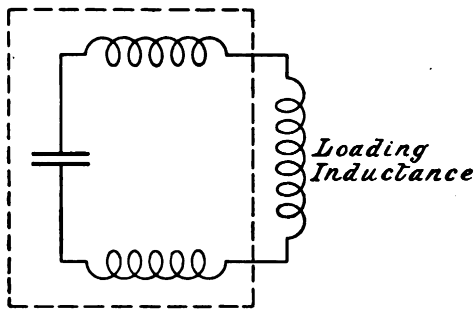
current registered on D. This point is obviously a node of potential.

This all goes to show the importance of having both extremities of an inductance unearthed. The reason is not hard to appreciate. If we have oscillating currents in one inductance the extremities will be at high opposite oscillatory potential with respect to each other. If one end is earthed as in Fig. 2 (*a*) the circuit as a whole must have a mean H.F. potential to earth, its field straying as indicated and inducing all sorts of dielectric and resistance losses in surrounding bodies. In Fig. 2 (*b*) however the nodal point is earthed and the potentials at the extremities of the inductance are symmetrical about this point, being always equal and opposite ; for this reason the electrostatic field of the various parts of the circuit will close on itself and very little will go to produce losses in neighbouring bodies. Quite a good analogy is found in the case of the tuning fork. If we hold it in the proper way by the tang and strike it, the fork will vibrate freely with low decrement. The tang is of course situated at a node and we may compare this case with Fig. 2 (*b*). If, on the other hand, we hold the fork by the extremity of one of its prongs it will not vibrate at all freely ; here we have the case of Fig. 2 (*a*).

The foregoing consideration undoubtedly explains to a large extent why the Hartley circuit makes such a good closed circuit and why the Colpitts and Reinartz circuits make such good "straight" circuits as far as input-to-aerial efficiency is concerned. Figs. 3 (*a*), (*b*) and (*c*) show the basic circuits of

these three systems with respect to earth. In (*b*) and (*c*) A represents the aerial-to-counterpoise capacity, which we must remember is always the condenser in the aerial oscillatory circuit. The Colpitts circuit, it will be noticed. has two natural potential nodes—one in the middle of the inductance and one at the junction of the two condensers if they are of approximately the same capacity. It will be found that with a closed Colpitts circuit that the best results are obtained with these two condensers of equal capacity, but when it is used in the more familiar manner as a straight aerial circuit the aerial-counterpoise capacity comprises one of these condensers, the other condenser, *i.e.*, the series tuning condenser below the A.T.I., usually requiring to be set at a rather larger value than the aerial capacity itself. It should be borne in mind that the usual aerial is not merely a capacity but has quite an appreciable inductance of its own, and this tends to complicate matters when we are working an aerial in the region of its fundamental wave-length, or below it, as the natural self-inductance of the aerial itself is quite comparable with any loading inductance we may have in the operating room. In this case it is necessary to picture our aerial system something as in Figs. 4 (*a*) and (*b*), the parts within the dotted lines representing the aerial itself. Even these figures do not exactly represent the actual electrical properties of an aerial as the inductance capacity and resistance are distributed together throughout the length of the aerial and counterpoise wires. Nevertheless the same general rules hold to a certain extent and it is still highly advisable to make the filament and earthed bodies natural nodes if it is desired to bring aerial losses to a minimum.

But to get back to some practical results. The same components that were used to build the circuit in Fig. 1 were rearranged first in the form of a closed Colpitts oscillator and then a closed Hartley oscillator. It was shown most decidedly that much larger H.F. currents were obtained in the Colpitts and Hartley circuit for a given input than in the case of the ordinary magnetic reaction circuit with the lower extremity of the plate circuit earthed.



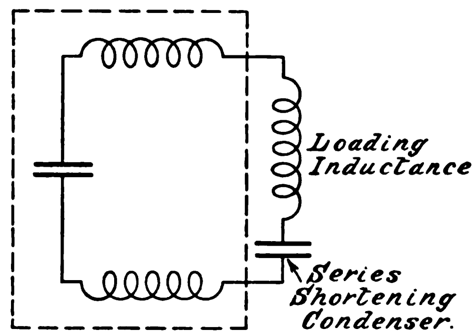


Fig. 4.—An aerial has appreciable inductance as well as capacity. The portions of diagrams (a) and (b) enclosed by the dotted lines are intended to represent that part of the total inductance and capacity of the aerial circuit which is contained in the aerial and counterpoise wires themselves.

An attempt was next made to substantiate our contention about the effect of the position of the nodal point on losses in an open aerial circuit. The aerial circuit was loose coupled to a closed Hartley circuit tuned to a wavelength well above the fundamental of the aerial, the aerial circuit being brought into resonance by a loading inductance and a series condenser. The series condenser was tried both above and below the A.T.I. as in Figs. 5 (*a*) and (*b*) with the thermo-ammeter always at the point A. With the series condenser below the inductance as in Fig. 5 (*b*) 10 to 20 per cent. more aerial current was obtained than with the condenser above the inductance. In both cases a hunt was made for nodes by touching various parts of the aerial circuit with an earthed wire; if any part at H.F. potential is touched, *i.e.*, any part that is not a node, the aerial current falls. In the circuit in Fig. 5 (*a*) no node

was found in the inductance, the potential gradient being continuous throughout its length; there was a node in the aerial lead somewhere above the series condenser. In Fig. 5 (*b*), the better of the two circuits, a node was found somewhere near the middle of the inductance as expected. Thus there

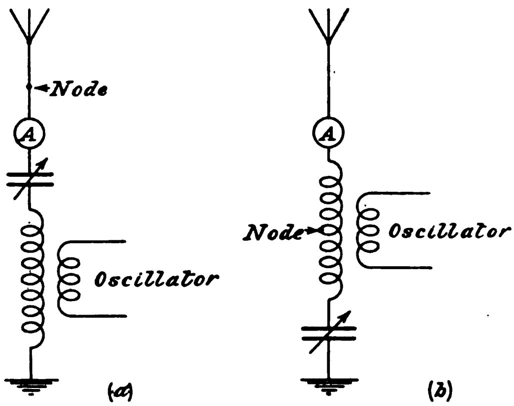


Fig. 5.—When a series condenser is used in an aerial circuit the position of the nodal point is dependent upon whether the condenser is placed above or below the loading inductance.

is a very fundamental difference between placing a series shortening condenser above the inductance and placing it below. The latter case is similar to the Colpitts in that the tuning capacity across the inductance is composed of two approximately equal capacities (aerial-counterpoise capacity and series condenser) the junction between which is naturally a node and to which the earth and filament leads are connected, leaving both ends of the inductance free to assume H.F. potentials. By actual test it will be found that both extremities of an inductance as in Fig. 5 (*b*) are at high H.F. potentials.

These tests on the position of the series condenser were repeated on a long aerial with high losses operating somewhat below its fundamental. Here the difference in aerial currents obtained with the condenser above and below the inductance was not nearly so marked—probably because the normal aerial losses were so bad as to mask any difference due to the two positions of the condenser.

The Colpitts circuit has a reputation for being better as a direct-coupled valve transmitting circuit than the magnetically-coupled reaction circuit, but the latter if used with a series condenser below the A.T.I. gives result nearly (but not quite) as good as those obtained with the Colpitts.

Loose-coupled circuits were also tried without any series condenser in the aerial circuit. This would appear to be the most straightforward thing to do where possible, and in some cases, particularly when only one or two turns of A.T.I. are needed, it is the best method. In other cases it has been found rather better to increase the aerial inductance and use a series condenser with reasonably low losses.

Effect of Series Condenser on Radiating Properties of an Aerial.

So far we have only considered the effect of the series condenser on the aerial circuit losses and the consequent damping effect. Another thing to be considered is what kind of electro-static field is being produced by the aerial—how it is distributed and to what extent it is effective in radiating waves in the desired direction. This is perhaps the most important consideration in the whole transmitting system as it is not much use radiating a large amount of energy into the ether with fairly high efficiency if most of the radiation goes in the wrong direction. It is true that most radio engineers do not attribute marked directional properties to small aerials such as most experimenters have to use; but the writer is at present chiefly concerned with the idea of short-wave working where the aerial is excited in

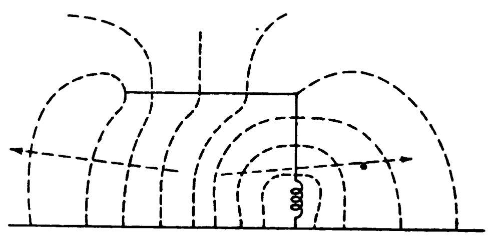


Fig. 6.—Field of inverted L aerial with loading inductance only.

the region of its fundamental frequency and cannot be considered as a capacity area pure and simple. In the case of an inverted L aerial, such as is so commonly used, there must be at any rate a certain amount of directional effect and all possibilities merit consideration when we are trying to unscramble the mysteries of short-wave transmission. An attempt has been made in Figs. 6, 7 and 8 to give an idea of the electro-

static field produced by a conventional inverted L aerial with a loading inductance only, with a series condenser above the inductance and with a series condenser below the inductance respectively. The counterpoise is assumed for simplicity to be an infinite plane—an assumption that must be modified if only a small counterpoise is used.

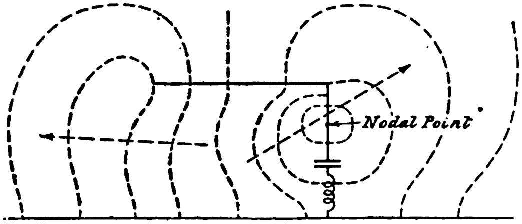


Fig. 7.—Field of inverted L aerial with series condenser above inductance. A node is produced in the aerial lead above the condenser.

Fig. 6 illustrates the simple case where there is no nodal point in the aerial above the earth connection. The waves will be propagated out into space chiefly in a horizontal direction or in a direction just slightly inclined to the horizontal as indicated by the dotted arrows.

In Fig. 7, for the reason previously given the series condenser causes a nodal point somewhere up the lead-in wire. It will be borne in mind that the H.F. potentials immediately either side of a nodal point are of opposite sign at any given instant; therefore the lines of electric force close on themselves about the nodal point distorting the field as shown. This will cause the field at the lead-in end to expand into space in a more vertical direction giving a direction of maximum propagation as shown by the inclined arrow on the right of the figure. The direction of propagation on the left would not appear to be much different from that in Fig. 6.

In Fig. 8 the condenser produces a node somewhere in the inductance which produces a distortion in field similar to that in Fig. 7 but which is less effective as it is lower down, more concentrated and well within the operating room. The direction of propagation from left to right will be similar to that in Fig. 7, though directed at a less steep angle to the horizontal, though more so than in Fig. 6.

The most generally assumed explanation for long-distance night effects on short wave-lengths is that reflection takes place at the Heaviside layer, thus allowing the waves to negotiate the curvature of the earth. If this is so it is an obvious advantage to direct one's radiation upwards at the Heaviside layer in the vertical plane of transmission, and it has been suggested that the suitable location of one's nodal point by means of a series condenser contributes to this effect. It appears then that the aerial in Fig. 7 would be particularly well suited to communicate with a distant station situated to the right of the diagram, while the directional effect of the aerials in Figs. 6 and 8 would not be so marked.

No hard-and-fast rules can at present be laid down as to the best position for the series condenser, or indeed whether one should be used at all in many cases. It has been pointed out that a series condenser brings in two important effects quite apart from the actual tuning of the aerial and a compromise may have to be sought between two possible arrangements, one which gives the greater valve-to-aerial efficiency and the other which gives the greater aerial-to-ether efficiency. Many experimenters' aerials depart considerably from the types of aerial which are usually treated in theoretical treatises. For instance, the operating room may be at the top of the house, or the aerial and lead-in wires may be at all sorts of angles

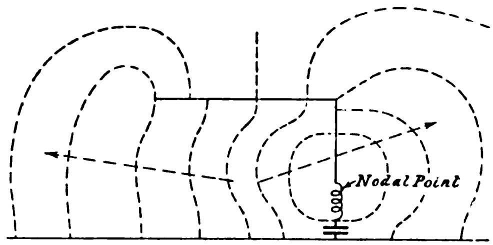


Fig. 8.—Field of inverted L aerial with series condenser below inductance. A node is produced somewhere in the inductance.

to each other and to the ground. Most amateur counterpoises are anything but infinite planes and often are not much bigger than the aerial itself. Then again, there is the effect of houses, trees, etc., in the neighbourhood of an aerial which may modify the distribution of the electrostatic field very considerably.

The only thing to do to get an idea of how an aerial is radiating is to draw a scale diagram of the particular aerial system under consideration and, having located by experiment the position of the nodal points (if any), in the aerial or counterpoise, draw in the lines of electrostatic force, bearing in mind the following important points:—

1. Each line must originate from a conductor bearing a charge and must start out at right angles to the surface of the conductor, no matter how it may be bent in passing through space.
2. Each line must terminate on a conductor at zero potential or opposite potential to the conductor from which it started.

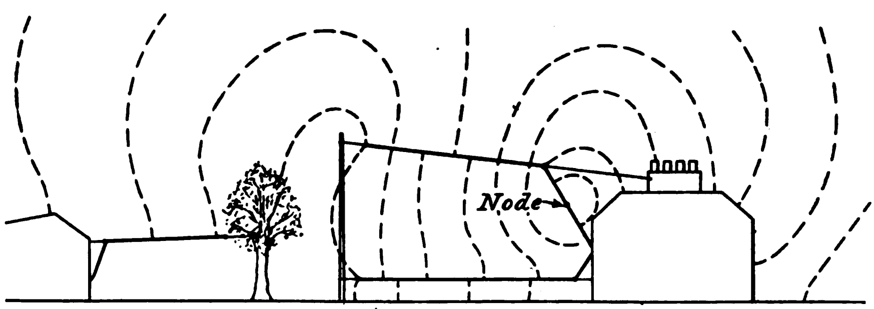


Fig. 9.—The field which may be expected in the case of a typical experimental aerial.

3. The lines try to take the shortest path to the conductor of opposite sign, but
4. Lines going in the same direction repel each other so that the field tends to bulge out.
5. No two lines ever cross each other.
6. Lines swelling outwards tend to be retarded by earthed bodies—rather as if they stuck to them.
7. The direction of propagation at any point is at right angles to the lines of force, that is the electrostatic field bulges out into space very much like the ripples produced on the surface of water by throwing a stone in.

Fig. 9 is an illustration of how this might be applied in a practical case. The fictitious man in the hypothetical villa is using a series condenser which produces a nodal point somewhere in his down-lead and owing to the fact that he is not on sufficiently good terms with his neighbours his counterpoise is not of the optimum dimensions demanded by theory. A rough attempt has been made to show the state of affairs at an instant of the H.F. cycle when the aerial is at maximum potential. All lines within a quarter wavelength of the aerial must end on the counterpoise or some terrestrial body. Those which do not end on the counterpoise will entail resistance and dielectric losses in houses and trees, not to mention the energy wasted in heating up the neighbour's crystal set. Note how the operator's house may get in the way of his own radiation.

The object of these few remarks has not been so much to tell the experimenter anything new about operating his transmitter but to suggest reasons for things that are observed and to direct greater attention to the theory of short-wave transmission. A great many experimenters get the best results at their own station by the laborious process of trying everything at random and obtaining reports from other stations. They finally arrive at the most efficient arrangements for their own particular stations and then do not alter anything nor do many of them worry about the circuits they have scrapped. We shall never get any result of scientific use, however, unless we put forward some definite theories and test them practically until we arrive at the hard facts of the case. What has been said above regarding the effect of a series condenser on loss and radiation resistances has only been partly verified by the writer, but no doubt other experimenters have a great deal of information to contribute on the subject.

Radio Station 5DN.

By CAPT. L. A. K. HALCOMB.

BRITISH 5DN is situated on the outskirts of Sheffield. The district is in a valley and far from ideal for a wireless station.

The aerial system consists of a two-wire inverted L type, the flat top consisting of two wires (7/22 enamelled), each 66 ft. long separated by 6 ft. spreaders made of

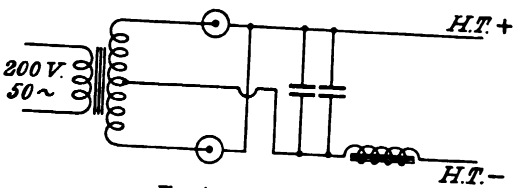


Fig. 1.—H.T. Supply System.

Simplex tubing. The lead-in consists of two wires, each 20 ft. long. Three earths are used, *viz.*, the water-pipe and two large copper plates buried under the aerial. The set, being on the first floor, entails the use of 35 ft. long earth leads.

A counterpoise 60 ft. long by 10 ft. wide made up of five wires solid 16 S.W.G. copper wire with a fan lead-in, is used in conjunction with the three earths. Incidentally, the addition of the counterpoise, when properly tuned, increases the radiation by 50 per cent.

The high-tension system consists of rectified and smoothed A.C.

Referring to Fig. 1, it will be seen that 220-volt 50-cycle A.C. from the mains supplies the high - tension transformer primary. Rectification is obtained by the use of two No. 3000 Amrad " S " tubes. These have given great satisfaction, and as there are no filaments in them they last, with care, almost indefinitely. Prior to the use of " S " tubes [ordinary rectifying] valves were used, but the filaments frequently burnt out, renewals becoming an expensive item. The makers of these " S " tubes state that 3,000 hours is the average minimum life, and that the maximum rating for them is 50 milli-amps. at 750 volts. If more power is required they recommend larger tubes.

The filter-circuit consists of two oil-immersed 2 mfd. condensers connected across the high-tension leads and a motor car spark coil secondary in series with the negative lead. This filter-circuit gives a very pure C.W., and from reports received on the quality of the note appears to be quite efficient.

Coming now to the set itself, the aerial and other inductances can be followed out by reference to the diagram in Fig. 2 and

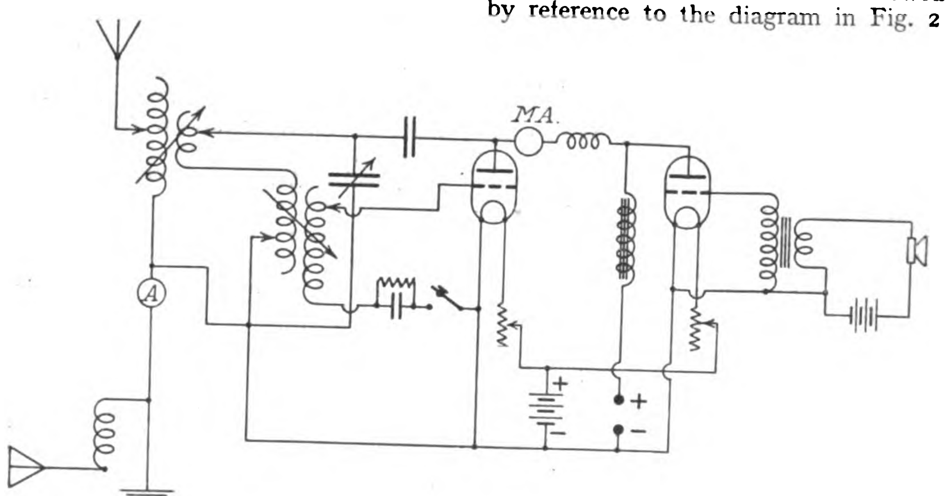


Fig. 2.—The Transmission Circuit used by 5DN.

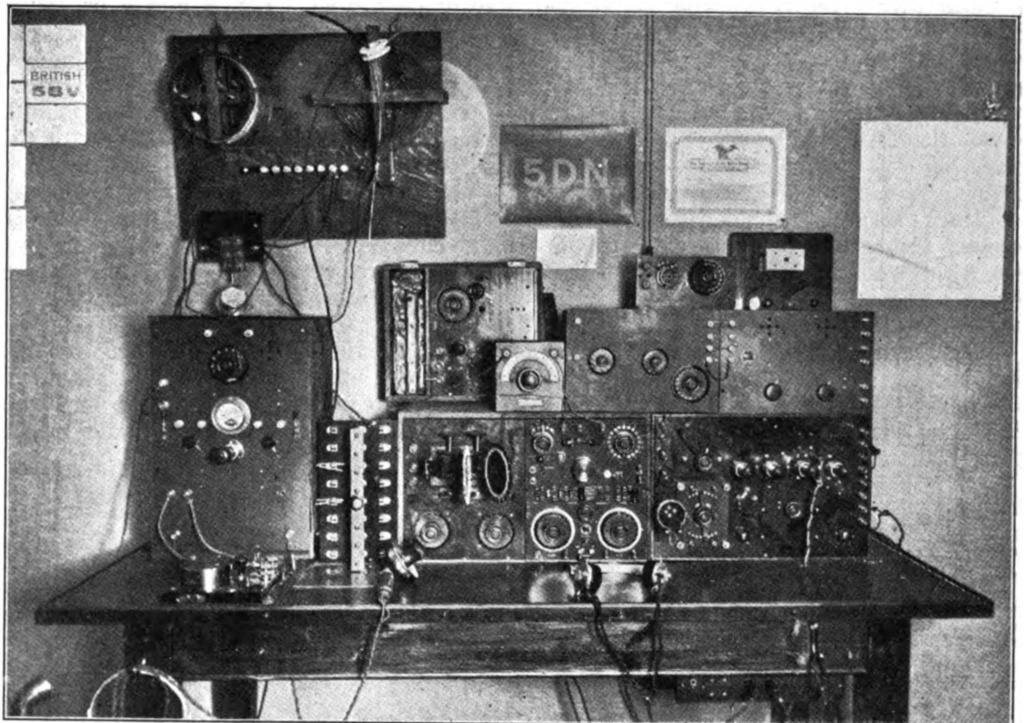


Fig. 3.—General View of Transmitter and Receiver.

the photograph. They are placed on a board on a wall. The secondary is wound in two parts, half being coupled to the grid coil and half to the aerial coil. The ammeter is in the earth lead and can be short-circuited when not required.

Looking at the transmitter panel on the left of the picture, the two terminals at the top lead to the closed circuit plate coil, which is tuned by means of a variable condenser just below the two terminals. Below this is the plate milli-ammeter, and below that is a bayonet socket into which a neon tube may be fitted. This latter is in series with the plate lead of the modulator valve. On each side of this socket are the filament rheostats for the power and modulator valves. Above each rheostat are two terminals to which a voltmeter may be connected to obtain the voltage on the filaments. A small knife-switch on the right breaks the modulator valve filament circuit when using C.W., and a similar switch on the left short-circuits the key when using telephony. The key is in series with the grid coil. Below the right-hand rheostat is a jack for the microphone. The H.T. terminals are placed at the bottom corners of the panel, and the remainder of the terminals are at the side behind the change-over switch. The valves used are Mullard o/20 for both oscillator and modulator. Two power valves may be used in parallel, if desired.

Using 10 watts (300 volts) on the plate of the power valve the radiation is ·6 amps. on C.W., and ·35 on telephony. Using this power the best "DX" on C.W. up to now has been two-way communication with Geneva and Venice. 8DY (Rouen) has been worked when he only used one valve and an indoor aerial for reception. Some months ago, before the ounterpoise was erected, telephony was received by 8BF (Orleans) on a 6-valve super heterodyne, but this has not since been repeated. These results seem to prove that large radiation figures are sometimes misleading.

Passing to the receivers, on the top is a short-wave tuner (range 85 to 220 metres) coupled to a two-valve amplifier (1 det. and 1 L.F.). This receiver is permanently inductively coupled, and cannot be used on

the "stand-by" position. The aerial inductance is untuned, consisting only of six turns of 16 S.W.G. D.C.C. wire wound on a former 3 ins. diameter. This receiver and three valves (1 H.F., 1 det. and 1 L.F.) receives KDKA direct quite well on 100 metres.

Below is the long-wave receiver consisting of a Mark III tuner. The primary and secondary windings are broken and brought out to a three-coil holder on the left, so that they may be loaded up to any wave-length. Switches provide for working on the "stand-by" or "tune" positions. The reaction coil is brought to the three-coil holder and has a ·0005 mfd. condenser shunted across it. The amplifier employs 1 H.F., 1 det. and 2 L.F. valves. The second L.F. is hardly ever used. Tuned anode or transformer coupling may be used at will. The former is generally used below 300 metres, and the latter for the higher wave-lengths.

Above the Mark III tuner is a ·00075 mfd. variable condenser placed in series with the Mark III earth lead. This has been found better for short-wave work than the ·0015 mfd. in the tuner, and the latter is therefore short-circuited.

On the top of the three-coil holder is a heterodyne wave-meter (range 88 to 665 metres).

The transmitter is now working on 200 metres, but it is proposed to work down towards 150 metres very shortly, and any reports of reception on the lower wave-length will be much appreciated.

The Month's "DX."

GENERAL REPORT, BY HUGH N. RYAN (5BV).

SINCE writing last month's notes the inevitable has, of course, happened. The annual curiosity which passes in this country for spring has come upon us, to the usual accompaniment of loss of signal strength. Transatlantic work has become increasingly difficult, and for long periods American signals disappeared altogether, and those of us who had prophesied "Yank signals right through the summer" on the short waves began to feel a bit doubtful. But, bad as things have been at times, a somewhat spasmodic touch with the "other side" has been maintained. We have just passed through such a period of extraordinary advance in British "DX," consequent upon the "discovery" of the virtues of the waves around 100 metres, that we have all become somewhat blasé. But consider for a moment to-day's doings in the light of last year's experience. What should we have said last year to the idea of working two-way with America, on low power, half way through May? We never expected even to receive American signals later than February or March, and two-way working in May is really a great achievement. I firmly believe, as does our "Northern Manager," 5JX, that we can keep up some sort of touch across the "Pond" right through the summer, if we try.

Of course the summer provides many counter-attractions to Radio, but "please, gang," as the Yanks say, give a little time to it occasionally and try to keep the work going right through the summer. It will be a great achievement if we can do it, so it's worth working for.

No very startling work has been done during the past month by the higher-powered stations. All of them have added to their "bag" of Americans during their work, but their maximum range has not increased. The less powerful stations, on the other hand, have been doing some very good work, many of them "getting over" on very low powers. Just too late for last month's notes I heard that 2GO (London) had been logged by 3CJY (Washington), input power being under 10 watts. Though London had every other district "beat hollow" in the pioneer work with America and Canada, and in the subsequent high-power working, the later low-power work has been almost

monopolised by the North. 5OT, 2PC, 2NO and 5JX have all been heard in America on powers below 20 watts.

Apart from Transatlantic work, very little of interest has happened. The Italians have been doing good work, 1MT having now bridged the Atlantic, and 1MT, 1ER and ACD having worked a number of very low-power British stations. 1ER is now heard regularly and very strongly in Britain.

Of the Danes, 7ZM is leaving Radio alone for a while owing to examinations. 7QF has packed up for the summer (though I doubt if he can keep off it that long ! !) and so the whole of the work falls on 7EC, whose signal strength seems to have risen to the occasion. His signals are very strong both on 200 and 120 metres, and he should soon reach America on the latter wave. By the way, I succeeded in relaying what was, I think, the first message from Denmark to America with the co-operation of 7EC. He suggested the attempt on May 9, and I told him that transatlantic conditions were very bad, but he gave me a test message and I was fortunately able to pass it on to American 1XAH within twenty-four hours. Danish experimental messages have been passed to America before, but they have come to England by post, and this was, I think, the first to go all the way by Amateur Radio.

At Easter the R.S.G.B. organised a four-day test to determine the range of members' transmitters. The tests were run like the transatlantic tests on a small scale, arrangements being made for listeners in France, Italy, Denmark and other European countries, as well as America and Canada. The tests were primarily for the lower-power stations, and at the end of each night's work a number of the higher-power stations (2KW, 5KO, 5BV, 2WJ, 5JX and others) who could be sure of reaching the various countries collected the reports. These, when published, should be interesting. Last month I suggested that a pure D.C. C.W. note was a very great help in long-distance work, and cited 2KF and 2NM as the only high-power D.C. stations in London. I forgot to mention 5LF, who, though not as powerful as the other two, is one of our higher-powered stations. I mention him now as his results bear out my last month's statement, 4th district American stations being able to receive him and 2KF through QRM and QRN, which blot out our A.C. stations.

We must use D.C. for Australia next winter. Speaking of Australia, in the March notes I spoke of the possibilities of our signals reaching that country, and, in view of the advances we had recently made, I prophesied that we should be working Australian amateurs within two years. I see that the American Radio Relay League Journal *Q.S.T.* has published my prophecy, and the reasons for it. This means that all the American amateurs, and, in fact, "hams" all over the world, since *Q.S.T.* and EXPERIMENTAL WIRELESS are read everywhere, will be expecting us to fulfil this prophecy. So it's up to us British amateurs. Let's do it next winter and make sure.

The MacMillan Arctic Expedition, with its amateur wave-length transmitter (WNP), provided an unusually fine opportunity for "DX," but our hopes have been sadly disappointed. I think many of us felt secretly sure that we should work him, but not only has nobody worked him from this country, but he has only been heard, and that very weakly, once by 5NN, once by 6XG and twice by 6LJ. There is still just a chance, but a very slender one, that someone may be lucky and connect with him, but even in America his signals have been almost inaudible since the beginning of February. I for one must confess to being very disappointed at not connecting with him. There used to be quite a rivalry between 5KO and me, as to which would work him first ! Well, 5KO has at any rate been heard by WNP around Christmas, so I suppose he wins on points !

The American Bureau of Standards, which is in close co-operation with the A.R.R.L, sends out very useful calibration signals for American amateurs, and these signals should be very useful to our men.

The call-sign of the "Bustans," as the Yanks call it, is WWV, and his signals have been heard by 2WJ and Italian ACD.

I cannot conclude without reference to a wonderful world's record, confirmed officially in America. 7ZU (Montana) has been received by 7ZU (Montana), the distance (round the world !) being 25,000 miles. Can any British station beat this ?

London District.

By 5BV.

REALLY, London, you haven't been showing up at all well during the last month. First, you have been letting the North beat you in low-power transatlantic work. Secondly, you have been filling the air with several new A.C. notes of perfectly awful QSB. Thirdly, you all forget to send me in your reports unless reminded every month. Come on, London, do brace up a bit and remember that "DX" records are not born, but have to be made.

We have been unfortunate in losing two of our best stations. 2NM is in America, and 2KF is now so busy that he has little time for Radio and none for "DX." Anyway, 2KF deserves a rest, since it was he who showed the rest of England "how to do it."

I think our outstanding performance this month has been on the receiving side. Although conditions have been very bad at times, 6LJ has been putting up perfectly wonderful logs of "Americans heard" right through the month.

On April 13 he logged 73 American amateurs and seven broadcasters in 2½ hours. He has logged over 500 Americans so far. Wish I could do that sort of thing! Our star receiving man, who could always be relied upon to hear anything that could possibly be heard, used to be 5NN, but he seems to be taking a protracted rest at present.

Of the high-power gang 2NM is absent and 2KF nearly so, but the rest (2OD, 2SH, 2WJ, 2SZ, 5LF and 5BV) have been keeping the ball rolling, without, however, any very interesting new records. All of them have worked a considerable number of Americans and Canadians, 2OD being far ahead of the others, and the number they work now depends only upon weather conditions and the energy of the operators.

One of 5BV's 150-watt valves has gone soft (inspired, doubtless, by the example of its relations at 2KW), and so 5BV's power is considerably reduced for the time being, but there are still enough available amperes for all European work and most American. By the time this appears full power should be again available.

The month's best all-round work has been done, I think, by 2WJ, who has worked eight Americans and Canadians. On one occasion he worked Canadian 1BQ, the latter using telephony most of the time. He has often heard 1BQ working other Canadians on 'phone. 2WJ also uses low power (3 to 10 watts) sometimes, and with this he has worked Danish 7EC and 7QF, and Italian ACD and 1ER. 2GO has reached America once on 8 watts. 5LF, in addition to excellent American work on about 50 watts, has worked all the possible European countries on 4 watts. Italy on 4 watts is, I should think, a record.

2ZT's last power valve has now given up the vacuum, so he is temporarily out of action.

5BT has worked most of the French and Dutch stations on a few watts.

2OD has sent the following summary of his transatlantic work, which is certainly a remarkable achievement :—

RADIO G2OD.

(Up to April 30th).

AMERICAN STATIONS WORKED.

1BBO	2AWF	3XAO	4BY	8AOL	9AZX
1XAK	2AWS	3OT	4XC	8ZAE	
1XJ	2BSC	3YO	4OA	8AVL	
1BDI	2AGB	3CKJ			
1BCF		3BVN			
1XAR		3BG			
1XW		3MB			
1CMP		3BJ			
1IV		3PZ			
1AJA		3ME			
1BSD		3ADB			
1JD					
1AUR					
1BLB					
1BCR					
1CAK					
1BVL					
1DZ					

Total American 40

CANADIAN STATIONS WORKED.

1BQ	2BN	3BQ	9BL
1DQ	2BE		
1DD			
1AR			
1BV			
1DT			
1DJ			
1EB			
1EF			

Total Canadian ... ... .13

Grand Total of Transatlantic Stations Worked 53

Input.—1,200 volts and 75 milli-amperes = 90 watts.

Radiation on 115 Metres.—2 amps. (Weston thermo-couple).

Effective Resistance of Aerial at 115 λ.—15 ohms.

Radiation Resistance.—12 ohms.

Transmitter Efficiency.—60 watts in aerial = 66 per cent.

Total Efficiency from Input to Energy Radiated.—Useful power radiated = 48 watts.

Therefore, total overall efficiency = 53 per cent.

One hundred and seventy cards reporting reception of signals from 2OD have been received from America and Canada, including one from 6AJU of California.

That is all the London news to hand. Not a very good show this month, but I'm sure a lot more good work must have been done. Will all London stations please make a point of reporting any "DX" work to 5BV at once, before they forget, and will those regularly engaged in "DX" please send 5BV a report of their month's activities by about the 10th of each month. We must keep up touch with America and Canada through the summer, and London is the district to do it.

Scottish District.

By 5JX.

THE chief feature in this district during the past month has been a large degree of inactivity, or if there has been much "DX" I have not got to know about it. There is only a very small handful of transmitters here, and the most of them have not sent in reports, so the record this month must be rather brief.

It may be possible that people are slackening off now because it is getting into the summer, and, if so, it is due to the mistaken idea that "DX" is inseparable from darkness. Fortunately this is not the case. Owing to the way transmitters seem to fight shy of daylight, much information from other parts is not to hand on this subject, but as far as this station is concerned daylight tests have been a complete success, and signals from the South have often been at least as loud as at night. For instance, 9 watts at 220 miles consistently readable a fair distance from loud speaker with standard 0-v-1 receiver while the sun is shining is not at all bad. Why not carry on throughout the summer? We with aerials sloping downwards to the far end might get better results by leading in there to an outdoor sitting in the garden, and at the same time show the neighbourhood how it's done! We would need a reliable weather forecast or we might have damped waves!

But, really, a lot of good men seem to be wasting their time by creating records as a sheer amusement. Apart from being illegal, there might be worse things than this, and, of course, quite a lot of good is effected in the search after general efficiency, but it is felt that a number could be doing still better work by making it more definite. As a suggestion, groups of two or more stations well separated might arrange a definite schedule of times for calling, covering all times of day and night, and send dummy messages in routine fashion, the idea being to discover the minimum power and apparatus to effect *reliable* communication over given distances *at all times*, and not at the most favourable ones. This divides up into distinct problems, such as atmospheric elimination, steadiness of wave, optimum wave-length, topographical conditions, etc., which could be definitely investigated by those concerned. Definite objects would lead to definite results.

Mention has been made from time to time of C.W. *versus* I.C.W. It certainly seems worth while using the former. Apart from questions of interference as regards effectiveness, one report, among others, gives 5 watts C.W. as better than 25 watts I.C.W. That is another point that might be further gone into. All that is required is organisation.

As regards results here lately, our district is at last QSO America. As was stated last month, for various reasons the "DX" stations had been all more or less out of action during the best of the American season, and only started in April. 2MG had the honour, and led off, getting across to American 2CPD on that very good day, April 6, using 30 watts. He has also communicated since. This was on 180 metres. 5JX, apparently the only other one to go in for this business, favoured 130, and later 112 metres, and on April 26 got over to Canadian 1DD, very QRZ owing to tremendous QRN and QRM. This was with I.C.W., but for reasons given it is hoped to do better soon on pure C.W., notwithstanding the lateness of the season.

Considering the scarcity of transmitters and the low power of those in existence, this result does not compare so unfavourably with those in the Southern districts as might be supposed. American signals are still very good here on the shorter waves, and in Europe nothing very important is reported. Most of those with mysterious calls may be fairly

safely put down as Belgian. 1CF is not yet located, and is reported very QSA over a wide area. 5JX is reported very good in Milan, but the latter (I1ER) has not been heard quite so much lately. Mr. Thompson, mentioned in our last, has taken to using an 8″×10″ frame instead of a 2 ft. He gets Yanks roaring loud on his single valve.

By the way, is it not time that a "DX" vocabulary were compiled? The meanings of all abbreviations, with historical notes! All attempts on the part of several to trace the exact origin of "73's" have failed. One sometimes shows "DX" cards to non-technical friends, forgetting they don't know the language. It at least has the merits of being international, and combines the advantages of Esperanto and shorthand.

I hope, at any rate, to have a few more reports from this area next time, and to hear something more interesting than QRK OM? when I std bi during the coming month.

East Anglian District.

By 2TO.

THE brightest spot in East Anglia just at present seems to be 5QV, situated at Clacton. On "fone" his record stands at being heard at Ancona, Italy, with a radiation of one amp. only. It is understood that a new generator delivering 2,000 volts is now coming into commission at this station, so may we ask you over in the States to QSL this station if heard at 3 a.m. G.M.T. on Sunday morning! At the first trial of the new generator the smoothing condensers emitted enough boiling pitch to asphalt the garden path! But that's a detail! The next station claiming attention is 6BT. Some good distances have been covered with a T.V.T. unit including "DX" to 5JJ Aberdeenshire. Reports of QSA have also been received from 7EC, W2, 8DP and many others.

2OF Lowestoft has at last installed a generator, and was heard chirping away the second week of May on 170. A great deal of trouble is experienced at Lowestoft owing to jamming from H.M.S. *Godetia* using call-sign ECP. Thank goodness he uses damped waves! At 40 miles the interefence is only just audible.

At Bury St. Edmunds also trouble is reported by "Constructors" going down to 200 metres and below whilst using "re-radiators." Now then, you chaps, play the game!

5TG Dovercourt is a very enthusiastic member of the family of East Anglians and it is to be regretted that the P.M.G. has not seen fit to grant him a radiating permit yet. 5JR, 6HA, and 5MA, all at Dovercourt, are very slow at making a start; 6HA is the only one heard to date. The great difficulty is that there is no power supply at Dovercourt, but a scheme is on foot to overcome this difficulty.

5ZW Tattingstone operates at week-ends occasionally, but again power supply is the difficulty. 2TO, the solitary transmitter at Ipswich, continues to cover good distances, cards having been received from 7EC, 7BJ 8EN, W2, and others. 'Phone "DX" is at present Northampton. The great difficulty at this station being the satisfactory rectification and smoothing of A.C. H.T. supply.

North-Western District.

By 2KW.

IT is gratifying to me to have received several good reports, and I hope that all those who have not yet let me have a *resumé* of their work will do so next month. Letters should reach me by the 6th of each month.

The news came to hand that 5OT (Colwyn Bay) has succeeded in establishing two-way communication with C1AR. At the time the aerial current at 5OT was 0·4 amp. Communication was maintained for about half an hour, and great credit is undoubtedly due to both stations for this very fine piece of work.

At last, at long last, G2PC has been heard on the other side of the Pond. Whether the Bug key did it or not we shall never know, but the fact remains that his signals were copied by U1BIG. The imput power at 2PC was at the time 15 watts, and the aerial current 0·7 amp. Although one of his masts has been damaged, he has stolidly "clung to his key," and has at last pushed it over. 5IK has had a fright. A response to a "Test" call was apparently made by C1AR on the night of April 6. It appears, however, that it was all a hoax. 5IK was using 200 volts D.C. for H.T. with an aerial current of

0·25 amp. at the time. Now that 5IK's hopes have been dashed to the ground, 2PC looks even more cheerful than when he first got across. 5IK has worked eight Frenchmen, six Dutchmen, two Belgians and two Rhenish stations, 8SSU and 1CF on the low power. 2PC has worked F8ML, 8EB, 8BV, NoNF, NoBA, LOAA, P2, while they have both worked Danish EC.

5AW (Southport) is our star low-power station. He has worked I1ER with an input power of 4 watts, and an aerial current of 0·17 amp. According to 1ER, reception was steady, with very little QSS. 5AW has also worked 7EC, while 8SSU, LOAA has been worked on 190 metres in broad daylight. Lately 3FF has reported him, and gives his position (3FF) as 500 kilometres S.E. of London. QSO, W2 and P2, 0BA has been worked using an input of 2 watts, ·12 aerial current, but signals reported QRZ. The aerial at 5AW is a single wire 50 ft. long by 50 ft. high. The counterpoise is a four-wire fan. 6NY Preston, who has transmitted over a distance of 20 miles, is using a loop. Several stations are QSO a new station, or rather an old station with a comparatively new call sign. It signs "YL." Anybody tuning to the wave-length of a heartbeat can get QSO this station quite easily, even if the valves are out!

5DN (Sheffield) is working on 10 watts at present, with about 0·4 amp. in the aerial. He has worked 1ER, and counting the Channel Isles, is QSO 13 countries.

5NH (Birmingham) is obtaining ranges of around 300 to 400 miles, and has worked 8BM on several occasions. 2TR and 2UF have both worked French and Dutch stations, whilst 2UF has been QSO 1ER and 7EC-2GW conducted some very interesting tests with ACD, the latter station reporting that he was transmitting on a power of 5 watts. This is believed to be the lowest power used by an Italian station when conducting a test with this country. 5BG reports things pretty slack in Huddersfield. He says that interference is terrible. We would like to hear from hams in that district. No news from Liverpool either. 2KW is on the air now and then and has worked 1ER and 1MT, also several other stations. His signals have been reported QSA by U8ZAV and by U9BEP.

The idea of many of our stations all over the country seems to work with as many different stations as possible. Whilst undoubtedly being of great interest, and possibly of some use, this policy will not lead us very far. I realise the great thrill that one experiences when a distant station is worked, and I can truly say that some of the most joyful moments of my life have been such ones as these. I am, however, convinced that without some specific object in view, it will not be possible for the amateur to say that he has made some definite scientific advance in the field of Radio Telegraphy. The astounding success achieved by many amateurs in covering great distances merely goes to show that they are expert manipulators of their gear—possibly expert designers—and wholly enthusiastic amateurs. Yet I am confident that unless we approach some of the baffling problems from a scientific standpoint we shall not be able to help in the solution of many problems which are admirably suited for amateur investigation.

Take, for instance, the problem of fading. Some preliminary observations were carried out by 2GW and myself some little time ago, with results that have already been made known to the readers of EXPERIMENTAL WIRELESS. It seems to me that the only way one may gain definite information on this and other points is that a number of stations devote themselves to the solution of one particular problem. I should like to see some definite move made in this direction.

If the more advanced amateur who has the necessary gear and the more necessary inclination would endeavour to co-operate with others on these points, highly interesting data would be available. Facts are needed before a satisfactory theory can be advanced. He would be doing a great public service were he to co-operate in the solution of some present mystery, instead of promiscuously flinging his signals about the surface of the earth. After reading the "Editorial," let us hope that everyone will be more alive to a sense of their responsibility not only to themselves, but to their fellows.

It is not my intention to try and belittle in any way the splendid work done by those who have so magnificently kept us in almost nightly touch with our American and Canadian cousins throughout the winter. They have shown us that the possibility of doing this can be regarded as almost a regular thing. It is of itself of high importance, for

we now know that were we to arrange schedules for scientific observations we might reasonably expect that our endeavours would be attended by some measure of success. But once the stunt is done the novelty ends, and it will be felt that unless we strive for something more than mere "DX" our position as a recognised section of the Radio community will become, to put it mildly, somewhat insecure.

Just before going to press comes the news that 5OT has been heard in Mexico with only 0·4 amp. in the aerial, and also that 2KW succeeded in raising American 1XAW and Canadian 9BL.

Western District.

By 5KO.

IN the West this month four whole stations reported their activities, so the task of writing the report is again a difficult one.

Transatlantic work here appears to be fizzling out for the summer. Both 5FS and 6RY report no new stations worked, while 5KO has only added Canadian 1AR and U3PZ to his bag. Reports of reception on the other side have been increasing, all three of our stations having been heard in the U.S. 4th District—5KO by 4BX, 5FS by 4BY, and 6RY by 4BZ, a rather curious coincidence. QRN has set in in earnest here, and it does not appear likely that any more transatlantic work will be done. 5KO has gone off the air to " swot " for a final exam., and will not be heard much until June is nearly over.

European work has continued as usual, and several new stations have been discovered. 5RQ, 6RY and 5WI (Dorchester) all report connecting with 1CF, believed to be located at Crefeld, Germany; 5WI's work being done on 1 watt, with 0.18 ampere in the aerial. He is also doing good duplex telephony with 5TN. 5FS has worked a new Swiss station, 9AA, who gave his address as Geneva. Italian 1ER is heard well in this district, working on about 125 metres with an A.C. plate supply: he has exchanged signals with 5KO, but usually appears to be engaged with 5SI of Shrewsbury, who is doing excellent work with his little M.L. generator running on accumulators. 6RY reports working 8SSU in broad daylight, and says European daylight work is easy after transatlantic stuff. He has also worked Danish 7EC, as have 5FS and 5KO—apparently 7EC has at last succeeded in his struggle to get down to 125 metres, and his signals are certainly terrific now. 5FS and 5KO have also connected with several Belgian stations with weird and wonderful call signs, such as 4C2 and P2. Why do they choose them, I wonder?

This week-end the district had the pleasure of a visit from 5MO of Newcastle, who arrived *via* 2KW and 5SI, spent Saturday with 5FS and Sunday with 6RY and 5KO, leaving on the Monday morning to visit the London crowd. Many yarns were exchanged, and it is felt here that such pleasant interchanges will be of great value in getting British amateurs to pull together. 7EC, 7QF and 5BV all promise a visit in the summer, and all this should improve amateur solidarity and cement friendships made " on the air."

Those interested in the noble art of wangling fresh concessions from the G.P.O. should be glad to hear of the astonishing success of 5FS in this direction. He is now the proud possessor of a 50-watt licence for waves of 20-40, 115-130 and 150-200 metres, and a 10-watt licence for all waves between 50 and 200 metres! At present he is on 125 metres, but is thinking about a drop to 40, when he can find out how to do it. An article on how to obtain such licences should prove a real " best-seller." Perhaps he will give us one?

A few apologies are necessary before closing this budget, first to 2NS for suggesting last month that he was dead: he resurrected for the T. & R. tests at Easter, and handed in a good list of calls heard. The second apology from 6RY and 5KO for inflicting " bug " sending on their numerous friends. They hope to improve.

In conclusion, one more appeal to Western stations. There are not many of you in the district, so it is all the more essential for every man who is doing good work to report, and help this section to keep its end up. Let's hear from you!

The Trend of Invention.

Reducing the Effect of Space Charge in Oscillator Valves.

It has been common knowledge for some time that the space-charge in a valve due to electrons between the filament and plate of a thermionic valve limits to a great extent the anode current which can be obtained for a given anode potential, and materially adds to the impedance of the valve. This defect has been overcome to a great extent by the introduction of a second grid between the filament and the usual control grid, the extra grid being given a slight positive potential to neutralise the space-charge. Such four-electrode valves have been made and used for reception purposes with only a few volts of plate supply for some time past, but our Fig. 1 shows how the same idea has been modified for transmitting valves. (British Patent 195,964, British Thomson-Houston Co., Ltd., and D. C. Prince.) The valve A contains a filament B, an anode D, and the usual control grid C. The extra space-charge grid E derives the necessary potentials, not from a bias battery, but from the H.F. potentials set up across the main inductance F. The object of the invention is to increase the efficiency of the valve and to render possible the use of

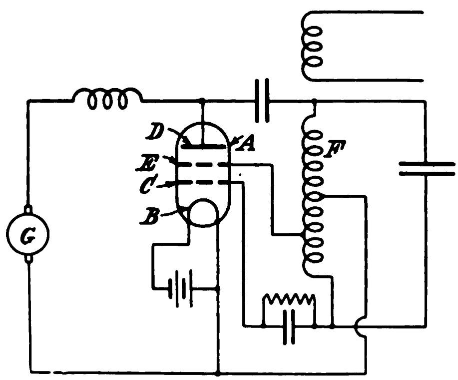


Fig. 1.—A device for reducing the effect of the space-charge.

lower plate potentials. It will be noticed that this invention differs from the usual four-electrode valve receiving circuit in that the space-charge grid is between the control grid and the plate, instead of between the filament and the control grid.

Elimination of Howling in Amplifiers.

It is very common for low-frequency amplifiers to howl at a very high-pitched frequency. Fig. 2 illustrates a method of suppressing regeneration at such frequencies (British Patent 193,010, C. Lorenz Aktiengesellschaft and W. Scheppmann). Across one

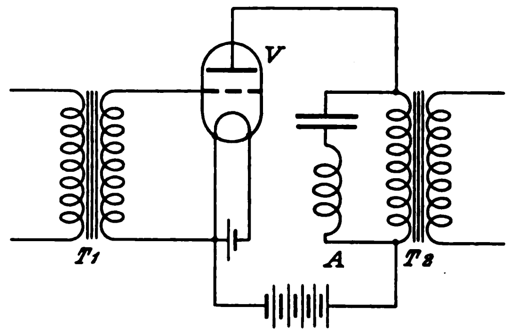


Fig. 2.—An arrangement for preventing howling.

or other of the intervalve windings is shunted a series resonant or acceptor circuit A, which is tuned to the offending frequency. Currents of this frequency are practically by-passed by circuit A, and, therefore, do not affect the intervalve transformer, T_2. This scheme for stabilising an amplifier looks as if it would be as effective as it is simple.

Anode Construction for Low-Impedance Power Valves.

In designing power valves capable of dissipating a large amount of power, it is necessary to use an anode of adequate area in order to dissipate the heat formed. With valves having anodes of the usual cylindrical type, it is necessary, in order to obtain the requisite surface area, to make the diameter greater than would otherwise be desirable. The result is that the distance of the anode from the grid and filament is rather large, and, owing to the space-charge effect, the impedance of the valve is high. Fig. 3 illustrates a recently patented method of overcoming this (British Patent 205,039, F. Peri). The figure is a cross-sectional plan, C being the

filament, B the grid, and A the anode. The construction of the anode rather resembles that of a certain type of chimney cowl, con-

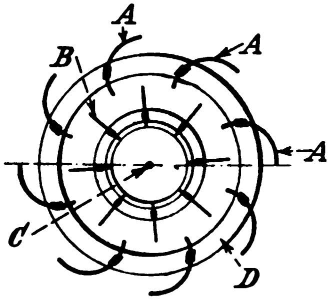


Fig. 3.—The construction of the electrodes.

sisting of a number of longitudinal vanes A which are given a curvature at right angles to their length and held between circular end-cheeks D. The grid may also be constructed of vane-like members B, which, however, are flat, and are arranged to occupy approximately the middle of the intervals between the inner edges of consecutive anode strips. This construction not only provides a large heat-dissipating surface at the anode, but also permits the effective distance between grid and anode to be greatly reduced, thus reducing the space-charge potential drop, and lowering the impedance of the valve.

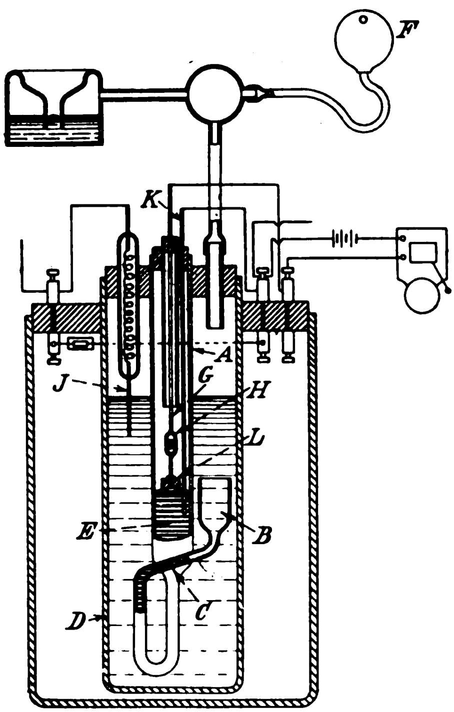


Fig. 4.—A capillary Micro-relay.

Capillary Micro-Relay.

Fig. 4 shows how the principle of the capillary electrometer has been used in the construction of a relay capable of being used in wireless circuits, etc. (British Patent 213,386, I. Kajino). Two vessels A and B are connected by a fine glass capillary tube C. A and part of C contain mercury, shown by the thick shading E, while the rest of C and the vessel B are filled with a mixture of dilute sulphuric acid and glycerine. B is in connection with

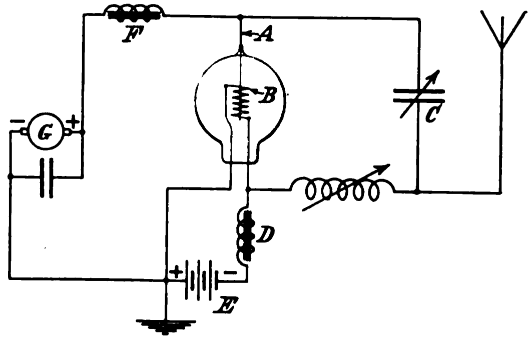


Fig. 5.—A magnetron without an external winding.

the outer vessel D, which is also filled with the sulphuric acid and glycerine mixture. The signal currents which are to operate the relay are applied by means of the electrodes J, K to the acid in D and the mercury in A respectively. If the currents are applied in the right direction the thread of mercury in the capillary tube C will creep up towards the vessel B ; the mercury level in A will sink slightly, and lower a float L, with the result that two hooks G and H come in contact and close a local indicator circuit. Most capillary electrometers are very slow in action, and this would appear to limit their application to relay work considerably, but possibly the inventor of the relay illustrated may have overcome this sluggishness to some extent.

Magnetron without External Windings.

The valve shown in Fig. 5 is of the magnetron type, that is, the electron stream is controlled by a magnetic field instead of by an electrostatic one. There are no external magnetising windings, however, the filamentary cathode B being of spiral formation, and carrying a normal heating current of such a value as to provide the necessary magnetic field. The anode A is linear and placed axially with respect to the spiral cathode. A choke D is inserted in series with the filament battery E in order that current fluctuations necessary for the production of the controlling magnetic field may flow through the spiral B, and not be short-circuited by the battery E. The anode is supplied with power through a choke F from a generator G. Although Fig. 5 illustrates a power oscillator, this type of magnetron may be used in receiving and amplifying systems. (British Patent 189,135, British Thomson-Houston Co., Ltd., and A. W. Hull.)

Improvements in Strip Aerials.

The use of strip aerials has found a certain amount of favour in certain quarters, and a recent patent claims to effect certain improvements in such aerials (British Patent 213,347, J. H. Cook). It is stated that ordinary plain strip twists about when in use,

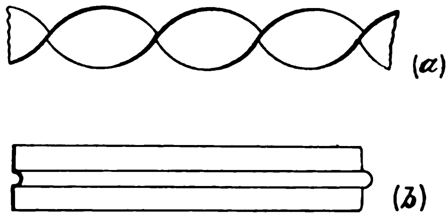


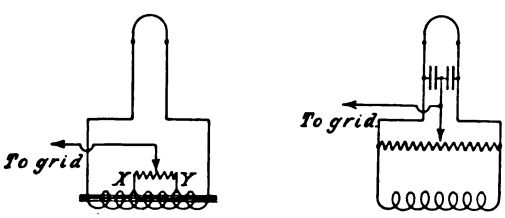
Fig. 6.—A new strip aerial.

and the surface area which it exposes in different directions is neither uniform throughout its length, and is not constant from one time to another. It is proposed in the specification to give a strip aerial a definite twist with a spiral pitch of, say, one complete twist per length equal to three times the width of the strip. Fig. 6 (a) shows a piece of such twisted strip. Before twisting, however, it is preferred to give the strip some form of longitudinal rib or corrugation, as in Fig. 6 (b), so that when twisted the strip will remain twisted. Various other means of obtaining such strengthening are described in the specification, as, for instance, using a number of strip vanes radiating from a common axis.

Experimental Problems.

Local Oscillators.

Several readers are apparently in need of a simple oscillator which is constant in operation and does not require coupling to its own oscillatory circuits; in other words, an oscillator consisting of a simple coil tuned by a variable condenser. This will mean the use of a dynatron circuit, which is difficult



Figs. 1 and 2.—Connections to filament transformer.

to manage, or else a valve which oscillates by virtue of some negative resistance effect such as the negatron, the patent rights of which are the property of Messrs. Radio Communication Co., Ltd. This valve, suitably connected with a single inductance, will oscillate between 100 and 25,000 metres. Personally, we see no objection why a tapping should not be made at the centre point of the coil and simply taken to the filament and an ordinary auto-coupled oscillator employed.

A.C. for Transmission.

The use of alternating current for heating transmission valve filaments seems to be causing a little difficulty. The centre tap method is, of course, well known, but is not quite satisfactory. One reader submits an arrangement (Fig. 1), but this presents the unnecessary difficulty of two extra tappings on the filament winding at X and Y; also, of course, there will be a resistance in the potentiometer to the H.F. grid currents. The arrangement of Fig. 2 is to be preferred as the same result is obtained, but in this case by connecting a 300-ohm potentiometer across all the filament winding, the sliding contact of which is connected to the mid point of two small condensers (about ·04 microfarads), the outsides of which are connected to either side of the filament, thus providing a free path for the oscillatory currents, and at the same time allowing the exact centre point of the filament winding to be obtained. The negative

H.T. is also connected to the slider, which is, in fact, the base line for all the connections usually going to the negative filament. One reader who is employing A.C. to light filaments and also work the primary of a T.V.T. unit will find it necessary to provide a separate low-tension winding for this.

Weston Relay.

Several inquiries have been received relating to the connections of a Weston relay, which we give in Fig. 3. A and B are the marking and spacing contacts, which are insulated from each other, while C is the connection to the tongue T *via* the hair spring. The input side to the relay is opposite the end carrying the tongue, and the current is led

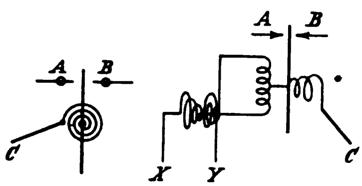


Fig. 3.—Connections of Weston relay.

through two other hair springs, which terminate in two stiff wires similar to C at X and Y.

A.C. Interference with Dual Circuits.

Alternating current seems to upset the proper functioning of many dual circuits. One of the best preventatives is that of screening the low-frequency transformers and placing all the grid leads to them in copper tube, insulated, of course, inside with "Sistoflex" sleeving. These tubes may then be connected together and earthed, or connected to a H.T. positive, whichever gives the better results.

Capacities of Condensers.

Several readers ask if it is necessary to adhere strictly to the capacities of various condensers which are shown in a given circuit. So far as variable condensers are concerned they may be made slightly larger if desired, which results in rather more critical tuning unless a vernier is employed, and will also increase the fundamental wave-length of the circuit. So far as grid condenser and also leaks in H.F. circuits are concerned, it is not usually essential that they should be accurately matched, although, of course, much depends upon the actual circuit. However, we would advise our readers to adhere to the values given, providing, of course, that the particular circuit has been properly designed.

Charging Accumulators from A.C.

Several queries have been received relating to charging 6-volt accumulators from A.C. mains by means of chemical rectifiers, and it is proposed to describe the method used at the writer's station. All accumulator charging is done by this method, and the transformer is used, which gives a secondary voltage of 25 volts. The rectifier cells consist of glass boxes 6 ins. by 8 ins. by 8 ins., and each contains aluminium and lead electrode measuring 7 ins. by 5 ins. The electrolyte consists of 75 per cent. saturated solution of sodium phosphate. Each cell of these dimensions will pass 4 ohms without overheating. If a larger output is required a sufficient number of cells in parallel are used to give the required number of amperes; thus for 12 amperes three cells in parallel are employed. In order that both a 2-volt battery and a 14-volt battery may be charged a 6-ohm resistance is used, made up from 16 gauge bare eureka wire divided into ten spirals fitted with selector switch. Each spiral is air cooled, and the whole suspended by two pieces of asbestos tubing having a core 3-16ths in. in diameter, and an overall diameter of ½ in. For general information a circuit diagram is given in Fig. 4, and it will be noticed that an ammeter is included in the circuit. This should be of the moving coil type, as a moving iron instrument introduces error. Though not shown, the rectifier cells should stand in a stone water bath, which, as a matter of fact, is an old stone sink, the water, of course, keeping down the temperature of the electrolyte, which is necessary for proper rectification. This method is found to be perfectly satisfactory, and has been used for 2½ years. The solution requires renewing after about 750 ampere-hours of charging, and provided pure aluminium and lead sheets are used a longer life than this can reasonably be expected, especially if care be taken that the electrolyte be not allowed to overheat.

H.F. Switches.

High-frequency coupling switches seem to present a host of difficulties to many experimenters, and it must be confessed that it is an extremely difficult matter to design really efficient switch gear for this purpose for anything lower than about 500 metres. The chief difficulty is that the electrode capacity and coupling device of the valve have a total value of more than enough to pass quite a reasonable amount of H.F. energy at the higher frequencies. Many people do not seem happy

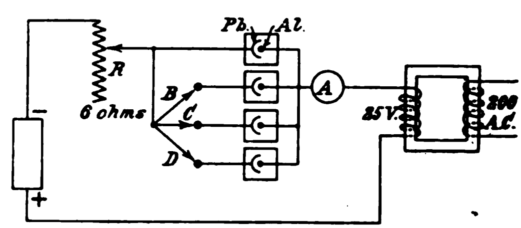


Fig. 4.—Accumulator charging circuit.

unless they can switch from one, two or three H.F. valves at will, and do not seem to realise the important fact that one stage of efficient high-frequency amplification on short waves (for example, the amateur band and the special 100-metre transmission) is of infinitely greater use than two or three stages inefficiently switched. The writer, therefore, does not care to recommend any switch gear with a clear conscience, as it has been found that, after extreme care in setting up three stage H.F. and detector circuit for KDKA, little, if any benefit was secured over one H.F. and detector even without switching, as it was not possible to keep the inter-valve coupling losses down sufficiently to be comparable with the extra amplification obtained. If switching must be indulged in, the writer would recommend a plug lead from

the top of the secondary circuit and plugged with a length of flex to the grid of the valve it is desired to use, at the same time disconnecting the lead from the anode of the receiving valve completely and intentionally mistuning all preceding anode circuits to avoid losses by actual absorption. The circuit used by the writer for the reception of KDKA is shown in Fig. 5. It will be noticed that the aerial is aperiodic and consists of four turns only. It is wound side by side with the secondary coil of an old Mark III tuner former, the two coils being separated by ¼ in., both being wound with the turns touching, *i.e.*, no spacing between consecutive turns. The tuned anode is wound on a section cut from the same former and mounted in a fixed position, the reaction coil being mounted so as to enable the coupling to be varied as wished. The condensers are ·0003 of the square law variety, the total wave-length range being 90—100 metres. All inductances except reaction coil consists of 20 turns wound with 16 double silk covered on

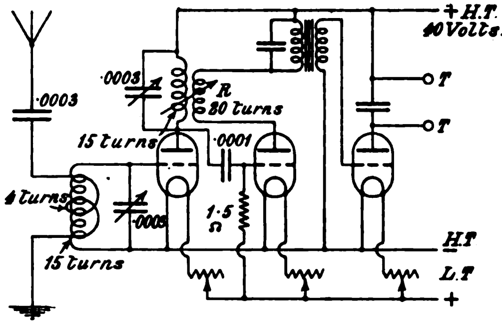


Fig. 5.—Circuit of reception of KDKA.

3½-in. diameter formers. The reaction coil is of the same diameter, but is wound with 24 double silk wire, and DER valves are used throughout.

L. E. Owen.

Direction Finding.

(Concluded from page 490, May issue).

By far the best construction for loops, working within the limits of wave-length mentioned in this paper, is to support them on five light spars, so that the dimensions of the loop are about 8 ft. high by 30-40 ft. wide, the apex being about 6 ft. above the upper outer corners. Spars about 25 ft. long with 6-in. heel tapering to 4-in. heads will generally meet the case, or a bridge can take the place of one of the

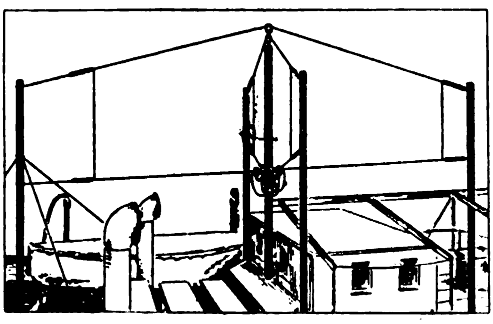


Fig. 1.—Direction-finder aerials supported on posts; s.s. "Motagua."

spars, or even of two of them. These spars must be placed with accuracy, the error of alignment of the sheeves not being allowed to exceed 1 in. Such an outfit can, as a rule be made absolutely permanent, and is independent of changes of temperature and the working of the ship in a seaway. Figs. 1 and 3 show various methods of attaching aerials.

The insulation of the apex of the loops is not of very great importance, but at all other points at least a 10-in. surface should be provided.

Very considerable trouble has been experienced in the past due to injury to the lead-covered cable between the loops and the direction-finder instrument. These are now generally run in steel conduits. Armoured lead-covered cable has been tried, and is satisfactory if either the lead sheathing or the armouring can be earthed at intervals of not more than 20 ft.; but, on the whole, plain lead-covered wire in steel conduits is the most satisfactory.

The ends of the paper cable are protected by cast-iron bifurcating boxes of the usual commercial pattern. When close to a compass wooden boxes are used. One of the minor difficulties of installing a direction-finder set in a ship is the protection of the ends of the paper-insulated cable from damp during the work of fitting.

After the loops are erected and have been proved to be geometrically correct and good for continuity and high insulation, they should be excited singly by a shunted buzzer as loops (not as plain aerials) and their wave-length checked. This should be below 400 m., preferably below 350.

The symmetry test should then be applied and, if the loops prove correct, the work of calibration can be commenced. But it is absolutely useless to attempt to calibrate until loop-tuning and lack-of-symmetry errors have been stamped out.

(4) Testing for Symmetry.

The principles on which a symmetry tester is arranged are as follows :—

Consider a single loop with its field coil. Let this be excited as a "plain" aerial—say by means of a shunted buzzer connected to a straight lead between the mid-point of its field coil and earth. If the loop under test is symmetrical current will be exactly divided between the two halves of the field coil and,

consequently, there will be zero resultant magnetic coupling between the field coil and the search coil. There will be a certain electrostatic coupling between the field and search coils, which will be greatest when the search-coil windings are nearest to the field coil under consideration. If the search coil is turned round clear signals will be heard in the

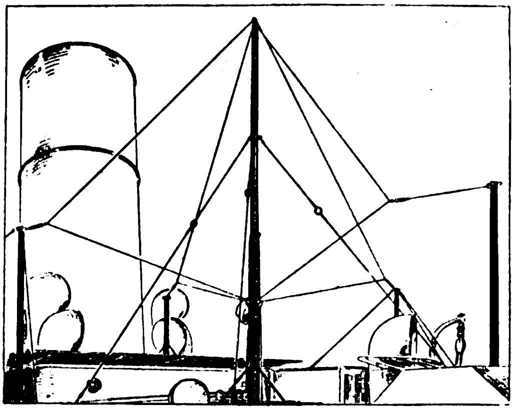


Fig. 2.—Direction-finder aerials fitted on posts; s.s. "Mooltan."

telephones, and the strength of signals should be adjusted by means of the coupling to the shunted buzzer until they are just comfortably audible at the maximum positions. If, now, one side of the loop be disconnected—giving the maximum lack of symmetry—signals will become very much louder and will be audible nearly all round the scale. A very slight lack of symmetry will cause a magnetic coupling between the field and the search coils, which will have its maximum effect in the same position as the electrostatic coupling. As the magnetic coupling is dependent on the sense of the windings, and the electrostatic coupling is not, these two will be in conjunction in one position of the search coil and in opposition in the opposite position, a slight lack of symmetry being betrayed by the fact that the signals are not of equal strength when the pointer is at these two opposite positions on the scale.

When both loops are joined to their field coils and the whole system is excited through its common mid-point as above, it might be expected that signals would (under suitable conditions of buzzer coupling) be just audible when the search coil was exactly inside each field coil, so giving four positions of audibility at 0°, 90°, 180°, and 270° (scale marked with 0° right ahead), but this is not the case, as the two combined electrostatic couplings have their maximum intensity at 45°, 135°, 225°, and 315°. This is possibly a peculiarity of construction of the instruments with which all available experience has been gained.

Hence the result of exciting a pair of properly symmetrical loops is to produce zones of clearly audible signals when the pointer is near to 45°, 135°, 225°, 315°, with well-marked silent zones around 0°, 90°, 180°, 270°. If one of the loops is but very little out of symmetry the silent zone about one of these points is obscured and signals at one pair of 45° are louder than at the other, with the result that signals become audible over a wide band about 0° and 180° (or 90° and 270°) with ill-defined minima between.

It has been found in practice that if the lack of symmetry is such that the zero is lost at 0°, 90°, 270° or 360° without destroying the perceptible maxima at the 45° positions, bearings will still be quite accurate when the mid-point is used unearthed, except for its static leak.

To sum up :—

(*a*) Perfect symmetry is indicated by signals of equal strength at the four 45° positions, with clear zeros between.

(*b*) Very slight lack of symmetry is indicated by signals at one pair of 45° positions being stronger than at the other pair, clear zeros still existing.

(*c*) Slight lack of symmetry is indicated by signals as at (*a*), but with the zero between the loudest positions obscured.

Bearings are still practicable under any of the above, provided that the mid-point is not earthed.

As the lack of symmetry becomes greater the maxima at the 45° positions disappear, loudest signals appearing with the pointer at one of the 90° positions. In all cases signals are loudest when the search coil is under the field coil of the defective loop.

These symmetry tests are very critical and easy to apply. They disclose any doubtful contact or poor insulation, as well as uneven distribution of inductance or capacity. Unhappily, they do nothing towards the detection of inductive lack

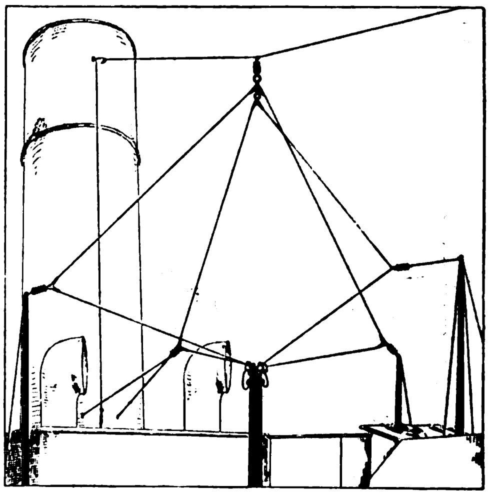


Fig. 3.—Direction-finder aerial hung from jumper stay.

of symmetry of the magnitude likely to be met with at sea, which can only be tested for the observation of external bearings with very strong signals.

(5) Calibration.

Calibration is perfectly simple provided that the ship is well clear of cranes, sheds, etc. A station having a bow or quarter bearing should be selected, and if the observed bearing is too near the fore-and-

Record of Working of Ships' Direction-Finders.

Name of Vessel.	Date Fitted.	1 September to 31 December, 1921 Total	Correct	1 January to 30 April, 1922. Total	Correct	1 May to 31 August, 1922. Total	Correct	1 September to 31 December, 1922 Total	Correct	1 January to 30 April, 1923. Total	Correct	1 May to 31 August, 1923. Total*	Correct*	1 September to 31 December, 1923 Total*	Correct*
"Ballygally Head" ...	25/12/19	—	—	66	66	3	3	7	7	18	18	17	17	†	†
"Cassandra" ...	17/6/20	17	13	†	†	20	7	15	8	†	†	77§	60	24	21
"Empress of Britain"	1/9/22	—	—	—	—	—	—	86	73	†	†	46	39	18	15
"Fort Hamilton" ...	27/7/21	5	5	21	21	†	†	3	3	14	14	8	6	19	17
"Kenilworth" ...	21/7/21	9	8	15	14	15	15	5	5	9	9	Unfitted			
"Metagama" ...	6/10/22	—	—	—	—	—	—	22	21	32	24	49	48	92	90
"Montrose" ...	24/3/23	—	—	—	—	52	45	15	13	42	39	66	52	75	71
"Olympic" ...	15/12/20	—	—	14	14	3	3	†	†	†	†	†	†	3	3
"Rosalind" ...	14/5/21	32	31	13	13	44	44	31	31	41	41	30	30	58	54
"Saturnia" ...	2/7/20	‡	‡	†	†	33	32	10	10	7	7	13	13	23	23
"Tortuguero" ...	14/12/22	—	—	—	—	—	—	—	—	103	79	76	73	98§	73
"Vauban" ...	2/6/21	25	15	42	27	26	24	9	5	14	8	11	11	12	11
Total for 99 ships	...	455	406	389	355	528	433	855	699	910	800	2,180	1,972	2,884	2,625
Percentage correct	...	89 per cent.		91 per cent.		82 per cent.		82 per cent.		88 per cent.		90½ per cent.		91 per cent.	

* With reference to the last two columns, *i.e.*, 1 May, 1923, to 31 December, 1923, the charts of bad bearing-arcs in St. Lawrence and English Channel districts were available, and bearings taken in these bad arcs are not included in the results given above.

† No reports received. ‡ Working satisfactorily. No details available. § Fault developed and removed.

aft line the fore-and-aft loop must be reduced—or the impedance increased—until the bearing is correct. If all other errors have been eliminated the correction of a single bow or quarter bearing implies accuracy all round, but it is as well to take some check observations.

Under practical conditions the fore-and-aft loop is usually about four-fifths the area of the thwartship loop, and a reduction of 1 ft. on each side of the bottom of the fore-and-aft loop will produce a correction of about 1° in a bow or quarter bearing. Such figures are empirical and very rough, but they give some idea of the state of affairs.

Calibration can be carried out only on or very near the bow and quarter bearings.

The final external test is for inductive lack of symmetry, which should be carried out with very strong signals very nearly right ahead and on the beam. In the absence of errors due to this cause the direction-finder can be trusted, but it must be remembered that the loops, and especially the lower parts, are almost as sensitive as a magnetic compass to the influence of external objects. A pile of Carless rafts placed temporarily under one limb of a loop, and a wet signal-halyard passing near one limb, have been recorded as producing errors of 5°, and a wire whistle-lanyard passing near one side of the fore-and-aft loop has been identified as the cause of an error of 14°.

It is well established that under conditions in which all the above can be eliminated, the errors of a Bellini-Tosi direction finder need never exceed 1°.

When using a direction-finder in a ship at sea it is imperative that the main aerial shall be completely disconnected from earth. Otherwise, large errors of a quadrantal nature will be introduced. If the main aerial passes close to either of the loops it is not sufficient to disconnect between the transmitting apparatus and the earth connections, the main aerial must be disconnected immediately it enters the wireless room. The reason for this is that there is sufficient stray capacity in the transmitter to allow so much current to flow in the main aerial that the resultant "loop" current is affected.

Calibration cannot be completed if the ship is lying near to cranes or dock sheds, although an approximate result can be obtained. The work must be completed with the ship at sea.

The symmetry tester will reveal the impossibility of calibration. A pair of loops which give excellent results and which testify perfectly for symmetry when the ship is at sea will appear to be hopelessly at fault if the ship is near to cranes, etc. The symptoms are different from those of slightly unsymmetrical loops—the usual effect being that the positions of all zero signals are slewed round bodily about 20°.

(6) Application.

Having established a direction-finder in correct adjustment, the problems of making full use of it as an aid to navigation can be tackled. The outstanding point is that a direction-finder takes relative great-circle bearings, that is to say, great-circle bearings relative to the keel line of the ship. These must be converted into true mercatorial bearings before they are of any use for navigation. If the ship is yawing, the observation of the direction of the ship's head at the moment when the

bearing was taken may be rather vague. The usual practice is for the operator to ring a bell when the direction-finder bearing is taken and for the direction of the ship's head by compass to be noted when the bell rings; and considerable combined practice between bridge and wireless room is necessary before the gap between a good direction-finder bearing and a serviceable true bearing can be filled up.

Taking all the above into account, for the purpose of making up the attached tables bearings are reckoned as being "correct" if they do not err by more than 2° from that worked back from a recent position by observation, 1° being allowed for residual direction-finder errors and operator's observation, and 1° for errors developing in the operation of translating the direction-finder bearing into a true bearing.

Direction-finder bearings at distances of over 50 miles are not as a rule of any great service, and at distances over 100 miles they are only a rough guide. This is not because of the liability to error being increased, but because the fix so obtained is so very rough in comparison with older established methods of navigation.

The position is considerably improved in ships where a gyro-compass repeater is installed in the wireless room. In such cases a "true bearing indicator" is fitted whereby the bearing is read off on the face of the repeater instead of on the direction-finder scale, and the true bearing can be arrived at in one operation.

It is obvious that the measurement of "direction" is in fact a measurement of the direction in which the plane of the advancing wave-front lies, and if this is not at right angles to the line of advance of the wave the direction as observed will be subject to error. Any such distortion of wave-front must introduce errors which cannot be detected at the receiver, and the well-known "land effect" and "night effect" are the common manifestation of this wave distortion. Night effect is generally accompanied by an unusual "woolliness" of zeros, but there is nothing to warn the observer of land effect except the general track of the wave when laid off on the chart. This is clearly the business of the navigating staff and not of the telegraphist, and more definite knowledge of the subject is required. Certain stations have a reputation for bad bearings, but there is not sufficient first-class evidence available to allow of a comprehensive statement being drawn up. It appears, in fact, as though land effect does not always occur, and certainly it varies considerably in extent. The general idea emerging from the records is that it occurs in two sets of circumstances:—

(*a*) When the line of bearing cuts a coast line—high or low—at an acute angle, say less than 20°; and

(*b*) When high land intervenes close to the receiver or transmitter.

It may be remarked that, so far, no effects have been associated with ice or fog banks.

An attempt has been made to overcome the difficulty of translating great-circle bearings into rhumb-line bearings by three methods: (1) Gnomonic charts are issued on which the great circles appear as straight lines; (2) a "half-convergency" table is issued from which the correction can be ascertained; (3) a "half-convergency" diagram is supplied from which the correction can be extracted. As a matter of navigation this correction is not of much value, as bearings at over 70 miles are seldom really used, and under 70 miles the correction is too small to be of any account.

It is worth noting that if two true bearings are laid off with station pointers on a gnomonic chart, the result amounts to a three-point fix, because the true north point forms the third bearing.

When all is said and done, however, deep-sea navigation is not the proper zone of usefulness of a direction-finder.

The typical direction-finder as described gives an ambiguous result, there being no distinction between a bearing and its complement. In order to distinguish this point direction-finder instruments are now fitted with a sense-finder, which is a form of the ordinary "heart-shape" receiver. As fitted in most ships the heart-shape diagram is by no means true, and the zero not as a rule good, and it is only used as an indication.

It is doubtful whether this sense-finding is of much real use for fixing the position of a ship, but it is very useful when working through cross-traffic in fog, and has sometimes been of great value in helping to pick up a vessel in distress which has been badly out of her reckoning and has announced a very bad position.

All remarks on direction-finding have so far been made with sole reference to spark telegraphy. Bearings taken of continuous-wave stations are very crisp and clear, but the wandering due to "night effect" takes place at times to so great an extent as to make bearings of continuous-wave stations quite useless for navigational purposes. This is usually the case after dark.

If a sense-finder is used, and if the plain component is balanced so as to give an accurate zero, then the position of that zero is not subject to wandering. The chief trouble lies in the fact that the rate of reduction in signal strength is not the same on both sides of zero, and therefore the position of zero is not midway between the vanishing points. Hence it is practically impossible to fix the position of zero of a continuous-wave signal with sufficient accuracy for navigational purposes.

The table on page 553 is a precis of the record progress made during the last two years in the adaptation of the direction-finder to the purposes of navigation in the mercantile marine. It consists of the details of the working of 12 ships taken at random from among 99, the totals for the whole 99 being shown at the foot of the columns. Some difficulty has been experienced in compiling this table, as reports are not perfectly regular and are not always fully detailed.

Bearings recorded as inaccurate include all causes of error, unless the direction-finder is definitely known to be out of action. "Night effect" is also included, but, since the approximate positions of "bad" areas have been promulgated, bearings which have been taken in known "bad" areas have been excluded from the list.

Correspondence.

Letters of interest to experimenters are always welcome. In publishing such communications the Editors do not necessarily endorse any technical or general statements which they may contain.

To the Editor of EXPERIMENTAL WIRELESS.

DEAR SIR,—With reference to Mr. Andrewes' article on "Receivers" in the April issue, I should like to make a few remarks. In these days we have to build receivers which are fully selective—far more than was necessary some time back—because of the interference, and I confess I was astonished when I saw the author booming variometers. When we first used tuned anode sets some used variometers and some used condensers, because variometers were then very scarce. We all believed that the lower our capacities for tuning the better. Then interference began to grow and we found this was not altogether true. Take the Hague, for instance. Gradually we found we had to use quite respectable tuning condensers on a plain circuit up to ·0005 mfd. We found that whereas all inductance was fine when there was not any jamming, it was impossible to do anything through the slightest interference. Of course, I am not talking about loose-coupled circuits at all. Anyhow, we found some capacity desirable; our signal strength undoubtedly dropped a bit, but the signal interference ratio increased. It does not matter if the signals rattle the 'phones, if the interference is louder still you are as badly off. This fact has been brought out all along as we have been progressing in the past few years that while theoretically inductance alone is best, actually we must have capacity to get the selectivity and get a good signal stray ratio. I do not propose to enter into theoretical whys and wherefores, but it is an experimental fact. If you don't believe it, try a test on a weak B.C. station on a bad night and see how much you can actually read one way or the other. However, to pass on. The modern variometer has a perfectly colossal self-capacity, and this is in the wrong place. While its large inductance ratio is good, a variometer has absolutely no place in a decent amateur receiver aerial or tuned anode circuit. The secret of decent reception is to use heavy gauge wire coils, spaced—and have everything most carefully spaced, far more so than is ordinarily done. Everything nowadays seems to be sacrificed to professional (?) looks. My ideal S.W. receiver is a ·0005 series or parallel (above 300 m.) series condenser and a large coil, say 4 ins. or 5 ins. diameter, with good thick wire tapped at a few points (as a compromise), with a similar though less spaced coil for the anode, and a ·0003 condenser reaction from detector to aerial. If decent plug-in coils (not of the usual kind) can be used, so much the better. If Mr. Andrewes would try this he need no longer complain that his H.F. amplifier does not. A properly made H.F. tuned anode really amplifies even with ordinary valves down well below 100 m. As an instance, my present set has two very rough anode coils. One for 400 metres is double the other in turns, and the smaller has a centre tap for 100 metres. These coils are not spaced but are of 20 D.S.C. close wound. They are far from ideal and should have been scrapped ages ago, but the results obtained are as follows:—On 400 metres amplification in volume by H.F. not great but quite fair, noticeable most on faintest signals; on 200 metres amplification is increased quite 50 per cent., while on 100 metres, using the coil with a big dead end, at least twice the amplification is obtained as is got on 400 metres. I know that results can be further improved to a large extent. Incidentally an amusing point is that hand capacity effects are less on 100 metres than on 200 metres! This is by the way.

The correct set to build is, in popular opinion at present, the three-valve H.F., det. and L.F. arrangement. I'd be willing to bet if a serious "DX" man, living in any sort of a congested area, cut off his L.F. valve and used only H.F. and det. for a month, he would not go back for normal work to

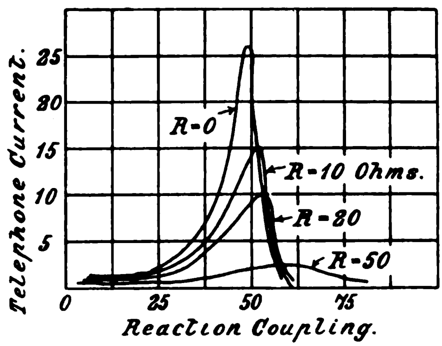


Fig. 1.

his note mag. It is all a question of what one is used to. At first the signals appear too faint to read, but after a time it will be found just as easy as before and far more accurate for interference will cause far less trouble. It is a question of operation. On only two valves the set had to be operated really carefully (that does not necessarily mean slowly) and the result is that the operator's standard rises and he gets better "DX." L.F. decreases the selectivity and this cannot be allowed.

As a little demonstration take the Americans. A year ago they used variometers invariably and lots of L.F. valves. This year their receivers are 100 per cent. better and they are using little or no L.F. and heavy wire coils, condenser tuned.

Finally, as regards resistance control. It is all very well in its way, but is from the root of things inefficient. Have a look at Stuart Ballantine's "Radiotelephony for Amateurs," page 209, Fig. 117, and see the effect of a resistance in the grid circuit of a valve with reaction. Anyhow, the circuit confines the oscillations to the first valve and is obviously going to be tricky. The author drew a veil over the oscillation nuisance. It is just as

well. I was fated to be 200 yards away from a certain person who was using this circuit. Suffice it to say that for six weeks we had to listen through the most appalling oscillation I have ever heard. The radiated wave was considerably louder than most transmitters heard on amateur waves. It was simply a case of go to bed! It was not as if the offender was a novice—by no means so. His heterodyne would literally wipe out any station, and of course his receiving strength was rotten. Reaction coils may have disadvantages but a little patient work helps a lot, and anything is better than what it would be if everyone tried resistances.

I have endeavoured to fulfil the author's hopes of a discussion and am anxiously waiting for my brickbats to be returned. To quote his words, "how dull our lives would be if everyone agreed!"—Yours faithfully,

FREDERIC L. HOGG.

INSIDE AERIALS.

To the Editor of EXPERIMENTAL WIRELESS.

DEAR SIR,—I read with interest the letter of Mr. Arnold Jowett on the above in your May number. Perhaps he and other readers may be interested in my own arrangement under conditions apparently approximating to his. I also have a large underdrawing running the entire length of my house (about 45 feet) and in it I also have erected an inside aerial as a substitute for a full length outside one previously employed. But whereas he arranges his turns horizontally I have adopted a vertical plan. My receiver is situated on the ground floor in a room at one end of the house. The lead-in goes through a window frame in the conventional manner and up the outside wall (in contact with it) and under a tile at the end of the roof. In the illustration a coil of 100 yards of ordinary double insulated (rubber and cotton) bell wire is connected to this insulated lead-in. The bell wire is secured to alternate rafters, to the ridge piece and the floor of the underdrawing by ordinary staples, forming a large diamond section coil of about 6 ft. 6 in. diagonals, the turns being approximately 30 inches apart (rafters spaced 15 in. centres). This coil extends practically from end to end of the house. An ordinary earth connection to a buried plate outside the window of the wireless den is employed.

The house is situated in a hollow, the South Downs rising some 650 feet above us within two miles to the southward while to the northward there is a rise which overtops the house within a few hundred yards. The axial direction of the aerial coil is exactly E. and W., the receiver being at the W. end. The mean height from ground level to centre of coil is about 25 feet, the house being a rather long low type of farmhouse. Roof tiled, fitted with iron gutters. A large cistern stands at the E. end within 6 feet of extremity of aerial.

On this aerial I can receive with absolute regularity and in daylight London, Bournemouth and Newcastle B.B.C. stations, and Brussels (410 metres), on one valve, using a modification of the Ultra-audion circuit which was evolved by myself, but I have since heard closely approximates to what is called the "Allbright" circuit, though without a choke coil. (A diagram of the circuit is given in Fig. 2.) After dark, and sometimes, under favourable conditions, in daylight, all B.B.C. stations, Brussels and the Ecole Superieure and the new 340-metre transmission of the Petit Parisien (the latter I believe only working on 500 watts) can be received on this circuit. Birmingham and Cardiff are the most difficult to get, Cardiff owing to its wave-length being so near that of London and Birmingham for some unexplained reason is always poor in this district.

The addition of a two-stage note magnifier brings London and Bournemouth up to loud speaker strength, indeed I have obtained readable signals from the former on the loud speaker from only the single valve. In this connection I should like to call attention to this circuit which I have found a most excellent one for single-valve work. The control to find the correct relative adjustment of variometer and variable condenser for best signal strength without howling is only a matter of a very little practice and once learnt the results are certainly superior to those I have been able to obtain

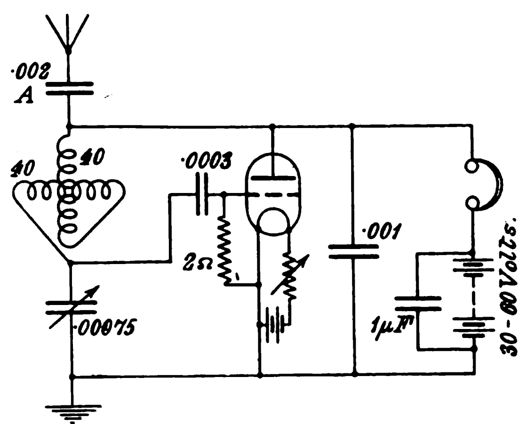


FIG. 2.

with any other single valver. The values of components given in the diagram are those arrived at by experiment on my own receiver. They might not be the best in all cases. My set is an "experimenter's" type of instrument mounted on an open oak panel without any attempt at compactness.—Yours faithfully,

HERBERT SHOVE.
Lieutenant-Commander, R.N. (retired).

To the Editor of EXPERIMENTAL WIRELESS.

DEAR SIR,—In connection with Mr. Jowett's letter in last month's number of EXPERIMENTAL WIRELESS I should like to say that during the trouble we experienced here last Autumn my outdoor aerial came down in double quick time, and after sitting on my thumbs for a fortnight I decided to instal one indoors. Having an air space under the roof (which are flat here) extending over the whole building, a single wire aerial forming three sides of a square was suspended from the beams. As much care was taken of insulation as with an outdoor aerial and consists of two porcelain shell insulators at each point of suspension. The total

length of the horizontal part is 90 feet with a down lead of 15 feet coming vertically through the ceiling, insulated by a glass tube. Using a single reacting valve signal strength is just right for headphones when receiving London, Bournemouth and Cardiff. Other B.B.C. stations are also received when the three mentioned are shut down (probably due to the home-made coils). Adding two L.F. valves an Ethovox loud-speaker comfortably fills a large room.

Although I have now installed a two-wire outdoor aerial preference is given to the indoor aerial, signal strength being slightly lower but with a very marked reduction in atmospherics and interference.

This is a very bad locality for wireless reception, being screened by a semi-circular range of hills to West, North and East, and all power and lighting distribution is carried out with aerial cables.

It is interesting to note that from the beginning of April to the end of October B.B.C. stations cannot be heard until about 15 minutes after sundown, when they come in at almost full signal strength ; incidentally, they are the telephone stations received at greatest strength, all other European stations being very poor.—I am, Sir, Yours faithfully,

BASIL HASTINGS.

To the Editor of EXPERIMENTAL WIRELESS.

DEAR SIR,—I have read with great interest and no little surprise your Editorial on "Amateur Transmissions" in the May issue. Taking the paragraph as it stands you state that the number of stations in the air has increased so enormously that the P.O. authorities must have relaxed their examination or the amateur had increased in his technical qualification. The answer to that is obvious. The figure prefacing the accompanying letters will practically answer it on its own. Nine-tenths of the jamming is due to people who persistently use fone for the mere pleasure of talking to one another, and a number of these have no right to be there at all; they are not aware of the first principles of radio operating, namely, the reduction of interference, and if you are working a very faint station, say about 200 miles away, on a special test one has to put up with two people talking to each other on about 50 watts at a distance of two or three miles on a subject that generally has nothing whatever to do with the test they originally commenced. It's not good enough, especially as some of their licences are very questionable and Morse qualifications in some cases *nil*. There are numbers of amateurs who are very keen operators and experimenters, and undoubtedly the refusal of the powers that be to grant them licences is due to the people that I have mentioned. The part of your paragraph I object to, however, is that dealing with the relay scheme. Surely an efficient relay scheme would not be evidence of inefficiency on the part of the amateur? Rather the reverse. In comparing the American scheme with our own, you must remember the difference in inputs. We have few 100-watt stations over here, and I venture to suggest that "*daylight*" work on 10 watts from Lands End to John o' Groats is not so easily accomplished as it sounds, and I cannot see why the authorities should not be interested in the undertaking. Such an undertaking in England, or, rather, the British Isles, would not be for the purpose of passing private messages, but rather experimental messages, and would certainly lead to the reduction of jamming, and much interesting data can be collected from intercommunication between stations in blind spots, etc. I venture to think that the new T. & R. section scheme will help towards this end. The unorganised chaos that is going on now is hopeless, and organisation must lead to a better condition in the Radio world. Where, then, is your argument? An easy method of placing a Scotch member in communication *during daylight* with a Kentish member will give us something to work on regarding the effect of night and day transmissions between those stations and the same with the scattered stations of the relay league. The use of "Test" seems to me to be the only way in which an isolated transmitter can get a report. If he is silent, awaiting a call, the other fellow may be doing the same thing. He cannot use CQ, he cannot use QST, so what on earth is he to use, and what harm is there in the use of the letters? In my opinion a relay league is the only solution to the terrible state of affairs now in being, and as such I earnestly hope that all transmitters will bear the fact in mind that wilful interference is doing the cause they love more harm than anything else can possibly do.—Yours,

W. W. CORSHAM (2UV),
Traffic Manager,
R.S.G.B. T. & R.

To the Editor of EXPERIMENTAL WIRELESS.

SIR,—I am much interested in the communications from Mr. Scroggie and Captain Finlay, in the April and May issues of your Journal, particularly with reference to the position of the aerial ammeter.

Captain Findlay says that "Mr. Scroggie's statement that the 'same amount of power is absorbed by the aerial ammeter in giving a reading, however it is connected,' is erroneous in this application," and he goes on to state that it is advisable to place the meter in a loose coupled circuit, as the decrement varies inversely with the resistance of the instrument under these circumstances, while the transformer loss operates against the loop circuit and not against the main circuit.

May I state that I consider Mr. Scroggie's statement to be correct, my reasons being as follows :—

Any meter requires a definite power input to cause it to register a certain deflection.

It may be connected in any direct manner but the power required remains the same.

If, however, we connect the meter in a coupled circuit the decrement of the complete circuit referred to the primary side increases with the resistance of the instrument. This may be proved by measurement on an impedance bridge.

May I suggest that Captain Finlay's contention that the power absorbed (coupled instrument case) is less, may be due to the fact that when calibrating his instrument he may have increased its range, *i.e.*, reduced the deflection and consequently the power per ampere input.

I find it difficult to understand the remark that the transformer loss operates only against the loop

current, since any loss or work done in the loop circuit must be made good by a corresponding amount in the primary.

The only advantage, in my opinion, in using a loose coupler is that, in the case of high resistance instruments, the decrement referred to the primary side may be reduced *by arranging a suitable ratio of transformation*, but given a particular transformer or loose coupler (fixed coupling) an increase of instrument resistance results in an increased decrement in the aerial circuit.

The principle is to a limited extent analagous to the induction coil in a telephone line, where the resistance of the line without the coil would cut down the transmitter currents to a very serious extent, but the insertion of the coil with a suitable transformation ratio enables the decrement referred to the primary to be reduced. It is only prevented from being a complete analogy by the fact that a H.F. current is used in one case and varying D.C. in the other.

With apologies for taking up so much of your space.—I am, yours faithfully,

O. S. PUCKLE.

To the Editor of EXPERIMENTAL WIRELESS.

DEAR SIR,—I note with interest "Kilo-Watt's" letter in your issue of May 2. I have succeeded in obtaining ½" sparks from an aerial 60 ft. long (double) and average height 35 ft. The occasions have always been during the summer months and during an exceptionally heavy rain or sleet fall. I quite agree that hail appears to charge the aerial to a higher P.D. than anything else.

It is also curious that I have never yet succeeded in obtaining the smallest spark in thundery weather although I have tried during quite severe thunderstorms.

Trusting that some of your readers will let us have a record of their experiences with, perhaps, some definite measurements.—Yours truly,

H. A. CLARK.

Business Brevities.

THE "RADIANT" H.T. BATTERY.

The accompanying illustration shows a high-tension battery recently placed on the market by C. A. Finchett, of Old Armoury, 1, Welsh Walls, Oswestry, Shropshire. The battery, to our mind, fills a want in the serious experimenter's equipment. The 60-volt unit shown in the photograph is contained in an oak cabinet fitted with terminals mounted on an ebonite plate at the side of the box. The battery consists of 40 cells each, contained within a wooden partition so arranged that any individual cell may be removed merely by loosening a terminal. This in itself is a good point, as, should a cell fail, it may be instantly replaced, and, moreover, unit cells are procurable at the price of 4s. per dozen. Insulation between the cells is obtained by covering then thickly with paraffin wax. The actual cells measure about 2 ins. by 1¼ ins., and accordingly are capable of withstanding a fairly heavy output such as is necessary for power amplifiers and sub-control amplifiers on telephony transmitters. We were favourably impressed with its performance on several heavy loads and short-circuit tests, and it seems to be capable of standing up to heavy work. The price of the 60-volt unit in an oak case is 19s. 6d.

Fig. 1—The Finchett H.T. Battery.

* * *

A NEW LOUD SPEAKER.

The "Concert Grand" model of the Graham gramophone attachment is, no doubt, too well known to need description. A new model, however, has just been produced, and is best described, perhaps, as being comparable with the well-known Amplion Junior. Considering the very reasonable price, it should make a special appeal to the reader, as it enables him to experiment with various types of horns and sound conduits. The new gramophone attachment, made by Alfred Graham & Co., is supplied with a rubber gasket, and is sold in a very neat box at the price of £2 2s.

* * *

IGRANIC COILS CHARTS.

Messrs. Igranic Electric Co., Ltd., have recently issued a very useful leaflet showing the wave-length range covered by their various coils when used either in a standard aerial or closed circuit. A copy of this publication should prove of value where experimental work on varying wave-lengths is involved.

"Wireless Telephony and Broadcasting."

"Wireless Telephony and Broadcasting" is the title of a very comprehensive work by H. M. Dowsett, who, of course, is too well known to need introduction to our readers. Mr. Dowsett's long association with radio engineering has enabled him to give almost an unique history of the development of wireless telephony, and this, in conjunction with a vast amount of practical information regarding both transmission and reception, makes the work of more than usual interest. To many amateurs it should prove invaluable. An extensive review will appear in a subsequent issue of Experimental Wireless.

* * *

Edison Bell Wireless.

Messrs. J. E. Hough, Ltd., have sent us a copy of their new catalogue describing their well-known Edison Bell Products. A special feature is a large selection of moulded ebonite formers, which seem so extensive as to be capable of meeting the demands of the most exacting experimenter.

* * *

The Ethophone V.

Messrs. Burndept, Ltd., have sent us a copy of a new booklet dealing with their well-known Ethophone V, which is of considerable interest as it explains a scientific instrument in a non-technical manner. Such publication is undoubtedly a wise undertaking, and should prove of great value in educating the general public in wireless matters.

* * *

Terminal Tags.

Messrs. S. H. Collett, of 52, Hampstead Road, N.W.1, have sent us some samples of their various terminal tags. There is a very extensive range of sizes, shapes, and finishes, including bright brass, tinned brass, tinned copper, and nickel. Readers who do not make use of terminal tags would be well advised to do so.

Accumulator Clips.

Messrs. The Runbaken Magneto Co., Ltd., have recently produced a pair of "Radio Clips" for use with accumulators. These should prove

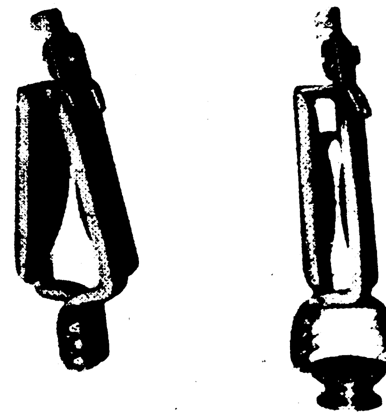


Fig. 2—Runbaken Accumulator Clips.

particularly useful to the experimenter, who is constantly changing filament batteries from one circuit to another. Those who charge their cells at home should find the clips invaluable on the two D.C. leads. One advantage of using a spring clip is that a positive connection is made with the accumulator terminals, which should tend to obviate any hissing noises sometimes heard in a receiver due to inefficient contacts. The clips are sold at 2s. 6d. per pair.

Recent Wireless Publications.

I.—TRANSMISSION.

La nouvelle station de Clichy.—R. Belmère. (*R. Elec.*, 5, 58).

A New Capacity Microphone.—D. F. Stedman, B.A.Sc. (*Exp. W.*, 1, 8).

The Meissner Transmitting Circuit.—I. V. Iverson (*Q.S.T.*, 7, 10).

Small Transformers for the Amateur.—H. F. Mason (*Q.S.T.*, 7, 10).

Radio Beacons, Non-Directive and Directive.—F. W. Dunmore (*R. News*, 5, 11).

The Production and Use of Ultra Short Wave-Lengths.—Prof. René Mesnv (*R. News*, 5, 11).

II.—RECEPTION.

Some Notes on Regenerative Receivers.—E. V. Appleton (*W. World*, 247).

Amplification without Distortion.—Louis Frank (*W. Age*, 11, 8).

Le récepteur Cockaday.—P. Girardin (*R. Elec.*, 5, 58).

Loud-Speakers and their Environment.—G. P. Kendall, B.Sc. (*Mod. W.*, 2, 8).

Faithful Reproduction in Radio-Telephony.—L. C. Pocock, B.Sc. (*El. Rev.*, 2424).

Receiving Measurements and Atmospheric Disturbances at the Bureau of Standards, Washington, September and October, 1923.—L. W. Austin (*Proc. I.R.E.*, 12, 2).

Short Period Variations in Radio Reception.—G. W. Pickard (*Proc. I.R.E.*, 12, 2).

New Applications of the Sodion Detector.—H. P. Donle (*Proc. I.R.E.*, 12, 2).

The Conditions for Distortionless Low-Frequency Amplification.—F. M. Colebrook, B.Sc. (*Exp. W.*, 1, 8).

The Damping of Diaphragms in Telephone Apparatus.—C. M. R. Balbi, A.C.G.I. (*Exp. W.*, 1, 8).

A Source of Loss in High Frequency Valve Circuits.—Capt. St. Clair-Finlay, B.Sc. (*Exp. W.*, 1, 8).

Experimental Notes and News.

In connection with the Olympic Games to be held in Paris from May 3 to July 27 the Marconi Company, in conjunction with La Compagnie Radio-France, has arranged for special facilities for the rapid transmission of telegrams between Paris and London.

* * *

Messrs. Burndept have recently installed an Ethophone V at the Vatican, and in recognition of their service His Holiness the Pope Pius XI presented them with a medallion of his likeness.

* * *

The wave-length of the Brussels broadcasting station is to be between 220 and 280 metres, depending upon the result of experiments.

* * *

It is understood to be the intention of the Burnley Corporation to levy a toll of 2s. 6d. per year on all who have erected an aerial wire over a public roadway.

* * *

Derby Day traffic will be controlled by wireless again this year. This year two wireless cars will be employed—one of a new type just built to the design of the electrical engineering staff of the Metropolitan Police, capable of operating at a speed of forty miles per hour.

* * *

It is probably that Leeds and Bradford will each have a broadcast station, controlled by one studio situated somewhere in Leeds.

* * *

The aerials of the new Rugby station are to be fixed on sixteen masts each 820 ft. high, which will dwarf the 300 ft. high masts of Leafield, Oxfordshire, the station which is to be the British end of the proposed British Empire chain of wireless communications. Already eight of the masts are approaching completion. Each one is nearly six times that of the Nelson Column (145 ft.).

* * *

Wireless enthusiasts in Greenock are not to be allowed to have their aerials crossing streets. The police have reported to the Corporation Street Committee that in about a dozen cases wires have been erected over public thoroughfares, but that in several cases when the householders had their attention directed to the fact that they were in the wrong the aerials were altered.

* * *

The preliminary conference for the drawing up of an international wireless telephony agreement has concluded its labours, and it has formulated, amongst others, the following conclusions: That certain wave-length fields should be exclusively reserved to wireless telephonic emissions, and that those allotted to wireless telegraphy should be clearly differentiated; That in view of the considerable contribution made by amateurs to the development and progress of wireless telephony, their rights should be taken into consideration, and certain fields reserved to their experiments.

* * *

It is understood that the Postmaster-General has informed the Imperial Merchant Service Guild that facilities for wireless direction finding are at present provided by the stations at the Lizard, Berwick, and Flamborough Head, and the question of the provision of additional stations at other points on the coast has recently been considered by an Inter-Departmental Committee.

Experimental Wireless

A JOURNAL OF RADIO RESEARCH AND PROGRESS

VOL. I, No. 10. JULY, 1924. 1s. NET.

Experimental Topics.

Transmission Regulations.

Since our last issue went to press we have received a number of communications from many of our readers who possess transmission permits to the effect that the Postmaster-General is considerably revising the conditions upon which they were originally granted. Moreover, the readers in question seem to be very perturbed at the impending changes, and it would be well for us to consider how the new regulations are likely to affect amateur work throughout the country. We would mention first of all the fact that we ourselves have received no official communication from the Post Office, but perhaps, of course, it may not be their intention to inform the technical Press. It appears, however, that the following is the substance of some of the more important clauses :

(1) Spark transmission to be forbidden.

(2) Wave-lengths of 150-200 and 440 (C.W. and telephony only).

(3) The wave-length of 440 metres not to be employed between 5 p.m. and 11 p.m., or on Sundays during the British Broadcasting Company's programmes.

(4) Messages shall be transmitted only to stations in Great Britain or Northern Ireland, who are actually co-operating in definite experiments.

(5) A record of all transmissions must be kept, giving complete details.

As a result of a very careful scrutiny of one of the "new permits," we feel that the Postmaster-General has framed his regulations upon the assumption that the average transmitting amateur wishes to transmit "for the fun of the thing," and is rather prone to regard amateur transmission as a hobby and amusement upon the same footing, perhaps, as golf, tennis, or even philately. We are obviously not in a position to determine exactly the technical ability of the average amateur, but we can definitely say that there are many men throughout the country of undoubted technical ability. On the other hand, there is also very definitely a large body of amateurs who (to use an Americanism) are nothing more than "hams." They transmit with the idea of sending messages. Their very language is an incomprehensible jargon of codewords, letters, figures, abbreviations, and cruelly murdered King's English, which is supposed to represent the result of their "scientific experiments." It is surely obvious that so long as this type of amateur continues to thrive, he does so as a menace to the freedom of the serious experimenter. The Postmaster-General is naturally liable to be influenced by a majority, and it is plainly the duty of the serious experimenter to raise a very strong objection to the continuation of these perfectly futile transmissions. There is no doubt that the present regulations are certainly more severe than the preceding ones, and may be taken as an omen of what is likely to follow unless every serious experimenter puts his case before the

authorities concerned. We have every reason to believe that the Postmaster-General is perfectly willing to give the serious experimenter as much freedom as possible; but, at the same time, it must be remembered that it is very difficult to make one rule for one and another rule for another. We ourselves feel that perhaps the Postmaster-General has been a little too lenient in granting permits. While we hold the view that the amateur should be given every facility for the study of transmission problems, we think that a higher technical standard should be demanded before authority is given for the use of a radiating system. The really scientifically inclined beginner would not raise the slightest objection to the use of an artificial aerial until he had learnt sufficient of the subject to warrant the use of a radiating system. Such a scheme as this would obviously raise the general technical standard amongst the transmitting amateurs, and, no doubt, the Postmaster-General would then have every confidence in granting greater facilities. The regulations as they now stand certainly impose a number of restrictions which are liable to hamper experimental work. Why, for example, is an experimenter, having devised a new form of quenched gap, to be prevented from trying it out. Presumably he has to suffer because many amateurs now possessing permits would not have the vaguest notion of how to tune a spark transmitter, and *might* cause interference. Why, also, is transmission to be confined to the British Isles? Possibly to remove the temptation to exceed the licensed ten watts on the part of an ignorant amateur whose apparatus is so appallingly inefficient that it cannot send to the Continent on even twice that power. And, again, why is the serious experimenter to waste half his spare time by recording in a log book such entries as: "11.42 p.m. Increased anti-regenerative coupling 5 per cent," or "Cut down drive feed by 10 milliamps." Once more, we suppose, to enable the authorities to locate easily some badly-adjusted station which is, perhaps, 20 per cent. off the correct wave-length.

We earnestly hope that the experimenter will fully realise the seriousness of his present position, and we strongly advise him, in his own interests, to show the authorities that he is strongly opposed to the promiscuous use of the æther merely for purposes of amusement. We have no doubt whatever that he will receive a welcome hearing.

The Month's DX.

It will be noticed that this month we have discontinued the regular transmission reports which have appeared under the heading of "The Month's DX." This does not mean in any way that we are going to eliminate the subject of amateur transmission, but merely that we propose to deal with it in a slightly different manner. Formerly, the reports have simply comprised a log of amateur work throughout the country, and while being of interest, have been of little help to other transmitters. In future we shall give, under the heading of "Amateur Transmission," details of definite experiments which have been carried out. We trust that not only those whose names have appeared regularly, but also many others, will assist us by sending in reports of their transmissions. The report should give details of the object of the experiment, the results obtained, and the conclusions which are drawn, together with full technical data. In this way it is hoped that the columns may be made of greater value to all interested in the subject.

The Experimental Laboratory.

As our readers are aware, for the past nine months a certain section of our experimental laboratory has been devoted exclusively to the free calibration of instruments and apparatus. Commencing with this issue, we propose to make some slight alterations in this direction with a view to making the laboratory of even greater value. From time to time articles have appeared in EXPERIMENTAL WIRELESS which have been the direct outcome of experimental work conducted in the laboratory. The appreciation extended to these articles has decided us to devote more time and space to similar experimental work, and in order to do this, we are obliged to restrict our calibration service to a certain degree. What we have arranged to do, therefore, is to limit the free calibration to our annual subscribers, and we draw their attention to the revised calibration coupon and conditions of service which will be found elsewhere in these pages.

The Prevention of Interference Between "Wired-Wireless" Circuits and Wireless Stations.

By E. M. D. (*International Western Electric Co. Inc.*)

No doubt many readers are familiar with ordinary "wired-wireless" systems. but it is thought that some details of the methods which have been devised to eliminate interference from wireless stations should be of interest.

IT is now a well-known fact that an aerial telephone line is not used to the fullest possible extent when carrying the voice-frequency currents corresponding to one telephone conversation, or even when it is used at the same time to carry telegraph currents. The telegraph uses frequencies from 0 to about 100 cycles, the ordinary telephone from 200 to about 2,000 cycles. It is possible to use the frequencies from 5,000 to, say, 30,000 cycles to carry additional messages. For each channel there is one "carrier" frequency which is modulated by the voice currents or by the telegraph relay. The modulated currents are sent over the line, selected according to their frequency at the receiving end, demodulated, and thus used to reproduce the original currents.

The telephone and telegraph channels using "wired-wireless" are designed to be practically free from mutual interference and from interference due to other "wired-wireless" circuits and ordinary telephone and telegraph circuits. Furthermore, the wired-wireless circuits are relatively free from ordinary interference from power circuits because of the high transmission frequency employed.

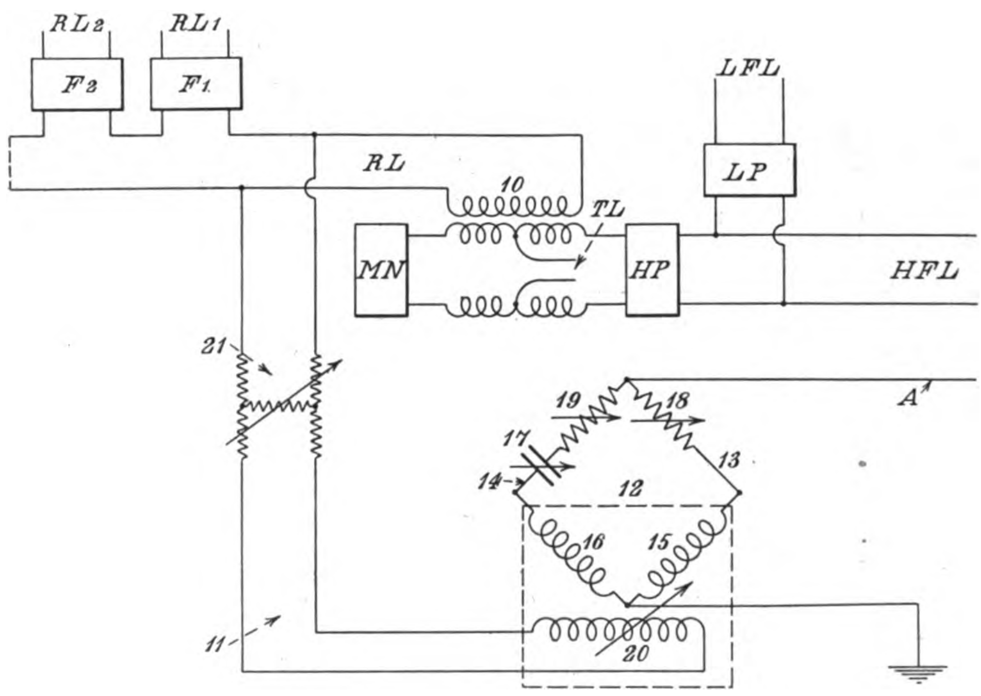


Fig. 1.—A System in which the Phase and Amplitude of the Balancing Potential may be Controlled Independently.

On the other hand, a certain amount of

interference is experienced from "statics" or atmospheric electrical effects, as observed in radio reception. This interference varies in amount from time to time, and is usually greatest in the summer months. There is, finally, a possibility of interference from high-power radio stations which use frequencies in the upper end of the carrier range. This may be serious where the wired-wireless line comes within 50 miles or so of the radio station.

It is, however, possible to balance out the radio interference in a wired-wireless circuit, and we propose to show a few methods of attaining such results.

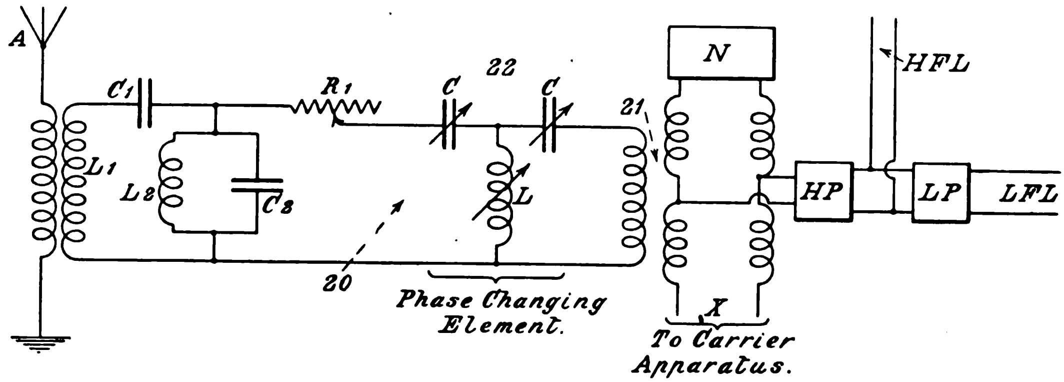


Fig. 2.—A System for the separate Adjustment of Phase and Amplitude.

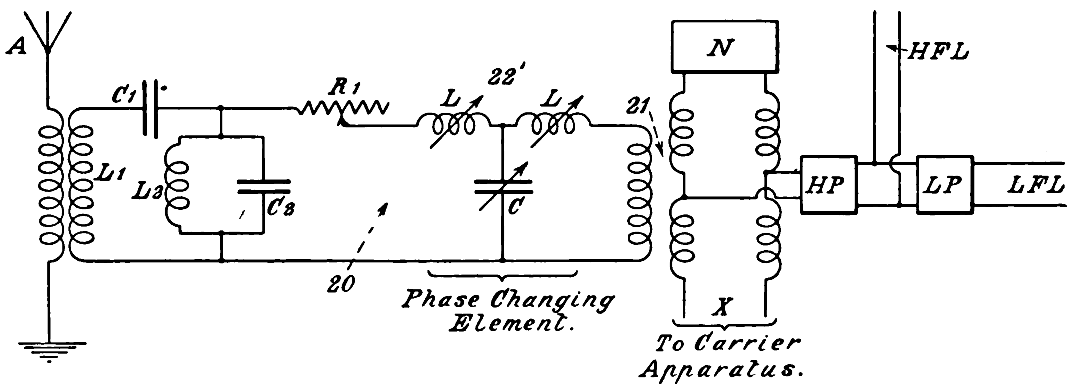


Fig. 3.—The Use of a Low Pass Filter as a Phase-charging Device.

It is necessary, when attempting to balance out the radio signals, to impress upon the wired-wireless line a signal of equal amplitude and opposite phase to the interfering signal. Some difficulty has been experienced in obtaining the proper balance, due to the fact that the adjustment of the balancing potential must be made in phase and amplitude. The circuit shown in Fig. 1 provides a system in which the phase and amplitude of the balancing potential may be controlled independently of each other. The circuit used for wired-wireless divides into a low-frequency line and a high-frequency line, the selection being obtained by means of a low pass filter LP and a high pass filter HP. The high-frequency equipment comprises a transmitting circuit TL and a receiving circuit RL. The separation between incoming currents and outgoing currents is obtained by means of a specially balanced high-frequency transformer TL, the balance being obtained by proper adjustment of the balancing network MN.

The various high-frequency receiving channels, such as RL_1, RL_2, etc., are associated with the receiving circuit RL through

suitable filters adapted to select the range of frequencies assigned to each receiving channel.

Let us assume that the main high-frequency line is subject to interference from a radio station employing a frequency within the range of one of the receiving channels—for instance, the channel RL_2. It is apparent that the interfering radio-frequency will be transmitted to the receiving channel RL_2 in the same manner as the modulated high frequency corresponding to this channel.

In order to balance out the interfering frequency a radio antenna A is provided which absorbs from the distant radio station the same radio signals as are impressed upon the line HFL, and this frequency may be impressed upon the channel RL_2 through the circuit 11 in opposite phase relation, but with the same amplitude as the interfering potential.

In order to adjust the phase angle, a rotary field phase adjustment is provided. This arrangement comprises two branch circuits 13 and 14, including suitable field windings 15 and 16 for producing the rotary field. In circuit with one of the windings, such as, for example, the winding 16, is a capacity 17, and in each of the branches resistances 18 and 19 are provided. Since the capacity 17 is included in one of the branches and not in the other one, the component of the frequency received from the antenna flowing through the winding 16 will be out of phase with the component flowing through the winding 15. The resistances 18 and 19 may be set so that both components have the same amplitude. Consequently, the two components energizing the two field windings 15 and 16 will produce a rotary field, which rotates at the frequency of the electromotive force impressed upon the antenna A.

A third winding 20 is placed within the field of influence of the windings 15 and 16, and by merely shifting the angle of the coil 20 with respect to the field of the coils 15 and 16 any desired phase angle may be obtained for the induced electromotive force in the circuit 11.

The amplitude of the induced electromotive force may be adjusted by means of series and shunt resistances 21, as indicated, the series and shunt resistances being adjustable together, so that, as the series resistance is increased, the shunt resistance is decreased, and *vice versa.* Under these conditions the impedance of the circuit 11 viewed from coil 20 will be constant.

The circuit described will, in consequence, provide a means of separately adjusting the phase and amplitude of the current. The phase adjustment may be made first by listening in the receiving circuit RL_2 and adjusting the position of the coil 20 until the interference is reduced to a minimum. The amplitude is then adjusted until the interfering disturbance can no longer be heard in the channel RL_2. The latter adjustment will not disturb the phase angle, and accurate balance may be obtained without difficulty.

The separate adjustment of phase and amplitude may be obtained in a somewhat different manner, which will be described now.

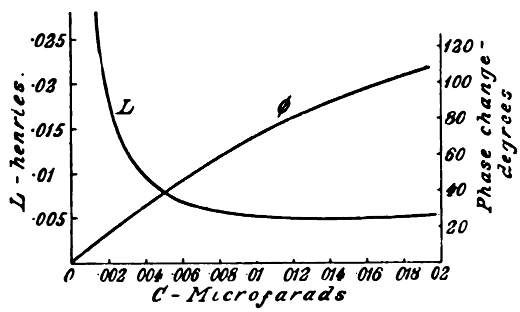


Fig. 4.—The Curve corresponding to Fig. 2.

The transmission line terminates in a manner similar to that described previously. Referring to Fig. 2, it will be seen that the circuit 20 associates the antenna A with the carrier branch X through a balanced transformer 21, so arranged that potentials from the antenna A will be impressed upon the carrier branch X, but will not be transmitted back through the high-pass filter HP to the high-frequency line HFL. The circuit 20 is tuned by means of an inductance L_1 and a capacity C_1 to the radio frequency producing the interference, and a shunt and a resonant combination comprising an inductance L_2 and capacity C_2 is bridged across the circuit 20 to shunt out other frequencies than the particular frequency which it is desired to use for neutralising purposes.

A single section of a high-pass filter 22 is included in the circuit 20 for producing phase changes in the balancing electromotive

force, and an adjustable resistance R_1 is also included in the circuit 20 for adjusting the amplitude independently of the phase-changing arrangement 22. The high-pass filter section 22 comprises series capacities C with a shunt inductance L bridged across the circuit at the junction point of the two capacities C. By adjusting the values of the capacities alone, or making suitable adjustments of both the capacities and the inductance, phase adjustments may be made

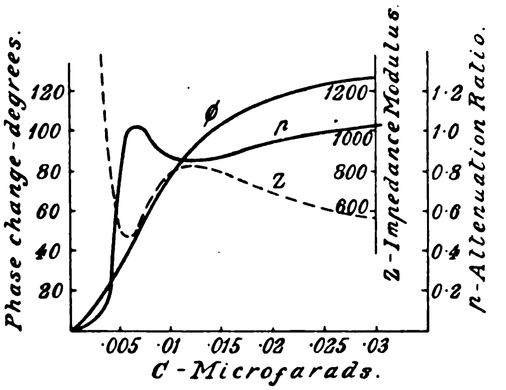


Fig. 5.—Characteristics of the Filter Section as Phase Changer.

without producing any change in amplitude. While this result may appear to be somewhat unusual, when it is remembered that a high-pass filter is substantially non-attenuating with respect to frequencies lying within its range, the reason for the result becomes more apparent.

In making phase adjustments by means of the high-pass filter 22 the inductance and capacity elements will be varied in steps, but the two condensers should be kept equal to each other. The relation between the inductance and capacity is given by the formula :—

$$L = \frac{1 + R^2 C^2 w^2}{2\,C w^2} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

in which w represents 2π times the frequency. The relation of this formula is derived on the assumption that, when one side of the network is terminated in a resistance of R ohms, the impedance, looking into the other side of the network, will also be R ohms non-inductive. The phase change due to the network is given by the formula :—

$$\varphi = \tan^{-1}\left[\frac{R}{Lw - \frac{1}{Cw}}\right] \quad \ldots\ldots\ldots\ldots \quad (2)$$

Curves computed in accordance with formulæ 1 and 2 are illustrated in Fig. 4, for the case in which the frequency whose phase angle is to be changed is 19,000 cycles, and the impedance of the circuit looking into the transformer 21 from the filter is 600 ohms. In Fig. 3 the curve designated L is the value of the inductance corresponding to each capacity setting of the capacity C of the filter 22. The curve marked ϕ shows the phase change for each adjustment of the capacity C, the inductance L, of course, being correspondingly adjusted. It will be seen that by varying the capacity from ·002 microfarads to ·02 microfarads the inductance L will be adjusted from about ·018 henries to about ·005 henries, and a phase change of about 90° will be obtained. The amount of this phase change may be increased as indicated by the curves by further increasing and further reducing the capacity. This may not be practical, however, as further increase in the capacity does not tend to produce a corresponding change in phase, while the smaller values of the capacity involve very sudden increases in the amount of inductance. Consequently, where phase changes materially greater than 90° are desired it may be necessary to use two filter sections in series to obtain the desired phase change.

It will also be noticed in the curve L of Fig. 3 the value of the inductance does not change materially over a very considerable variation in the values of the capacity of the filter, the curve L being almost flat through a large part of its range. This at once suggests that the network may be simplified by maintaining the inductance constant and only adjusting the two capacities. The curves of Fig. 5 illustrate the characteristics of the filter section as a phase-adjusting system for a frequency of 18,750 cycles with a terminal impedance of 600 ohms and a non-adjustable shunt inductance of ·006 henries. The curve marked ϕ indicates the phase change corresponding to different values of capacity. The curve marked p represents the variation in ratio of the current flowing into the 600-ohm impedance with the filter in circuit to the current which would flow into the impedance with the filter removed. Obviously, if the filter introduced no attenuation at the frequency under consideration, this ratio would

be unity. An examination of the curve p' shows that for a capacity range from about ·0055 microfarads to somewhere over ·03 microfarads this ratio does not depart excessively from unity, and consequently the phase adjustment over this range may be obtained without material change in amplitude of the current. The phase change corresponding to this change in capacity runs from approximately 35° to approximately 125°, a total phase change of about 90°. It is not practical to make adjustments outside of the range indicated, for an increase in the capacity does not produce any substantial phase change, while a decrease in the capacity below the value ·0055 produces a very marked increase in attenuation and also results in a very sharp increase in the impedance of the filter, as indicated by the dotted line curve Z. Where phase changes greater than 90° are desired it is best that two filter sections in series should be used, so that the first section will shift the phase 90° and the second section by a corresponding adjustment will shift it 90° further.

Fig. 3 illustrates a modified circuit in which a low-pass filter section 22′ is used as a phase-changing element. The other features of the circuit for balancing out interference are the same as those of Fig. 2 and need not be described. The filter section comprises a shunt capacity C connected to the mid-points of two half-section inductances L. The inductances should be kept equal to each other, and the relation between inductance and capacity for different adjustments of the filter is given by the formula :—

$$C = \frac{2L}{R^2 + w^2 L^2} \quad \ldots\ldots\ldots\ldots\ldots\ldots (3)$$

The phase change due to the network is given by the formula :—

$$\varphi = \tan^{-1}\left[\frac{2RwL}{R^2 - W^2 L^2}\right] \quad \ldots\ldots\ldots\ldots\ldots (4)$$

The characteristics of this type of filter as a phase-changing system are shown by the curves of Fig. 6 for the case of a frequency of 18,750 cycles and terminal impedance of 600 ohms. In Fig. 6 the curve L gives the values of inductance corresponding to different values of the capacity, while the curve marked ϕ indicates the phase change corresponding to each capacity value. The type of filter employed in Fig. 2 involves only one variable condenser instead of the two necessary for the high-pass type of Fig. 1, but in this case a fixed inductance cannot be used as the inductance varies materially for each material change in capacity, as indicated by the curve L. There is no part of the curve in which the inductance stays reasonably constant over a range of capacity changes. This type of filter, however, has the advantage that a greater phase change is obtained with a single section of the filter, so that in most cases it would not be necessary to use two sections. For example, if the inductance be varied from zero to ·014 henries, a phase change from zero to 140° will be obtained. The capacity will be varied from zero to a maximum of slightly over ·014 microfarads, and from this maximum point the capacity values fall off with further increase in inductance to a value of about ·009 microfarads.

If desired the inductances L in the filter section 22′ of Fig. 2 may be so wound as to have a certain amount of mutual inductance. In general, no advantage will be gained by this, however, as a greater phase change per section is possible when the mutual inductance is zero.

In the arrangements of both of Figs. 2 and 3 the filter sections may be adjusted

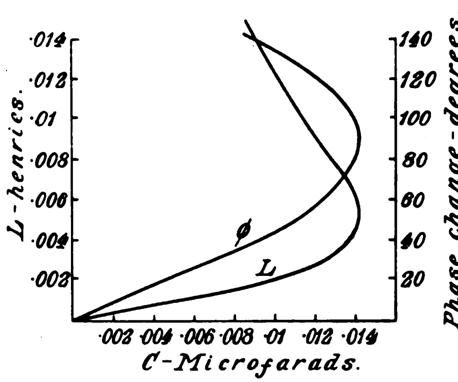


Fig. 6.—Characteristics of the Low Pass Filter.

to produce the desired phase angle for the balancing component without producing any material change in the amplitude of the current, as the filter section is approximately non-attenuating. Adjustments in amplitude may be made by a simple series adjustable resistance R_1 included in circuit 20. Variations in the resistance R_1 will produce little or no effect upon the action of the filter

section as a phase changer. Consequently, the phase and amplitude of the current may be independently adjusted.

A second method of preventing the interference due to a radio station on high-frequency wire circuits originates from the following considerations :—

The interfering frequencies on the wire circuits are due to potentials induced in the two sides of the transmission circuit in parallel. Ordinarily it would not be expected that such potentials would affect the circuit in parallel and impressing the derived current serially upon the circuit in opposite phase relation, but with the same amplitude as the serial disturbance flowing through the bridge.

The circuit used is shown in Fig. 7, where HFL and HFL′ designate two carrier transmission lines, which have similar characteristics and are subject to similar interference from a radio-transmitting station. The lines HFL and HFL′ terminate in the same manner as that described in connection

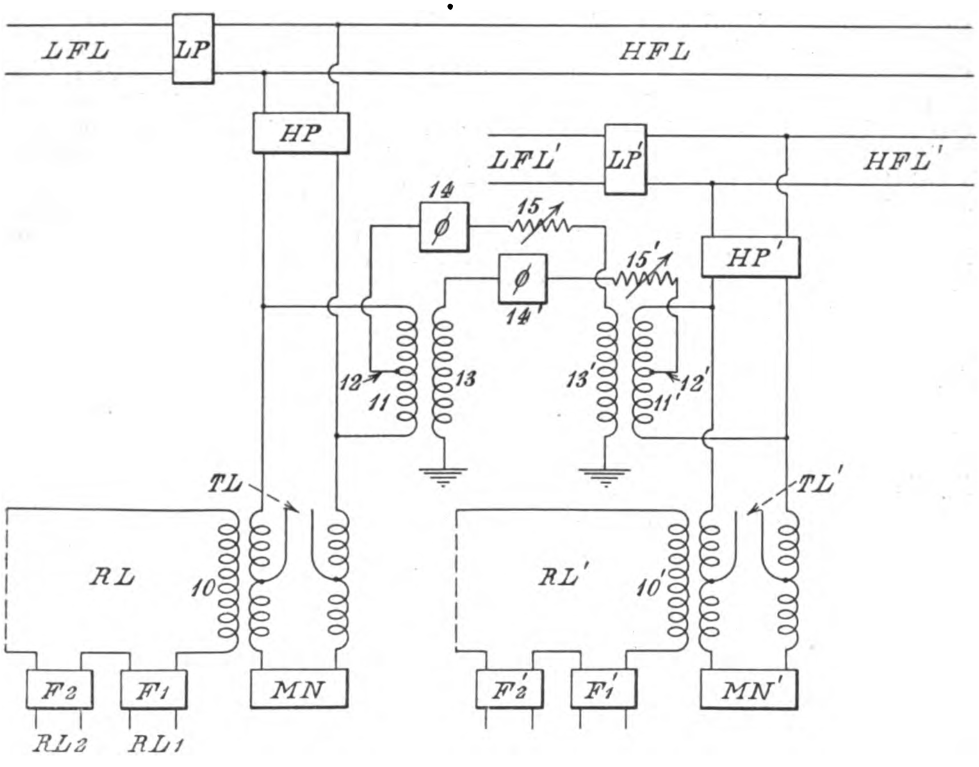


Fig. 7.—A Practical Circuit Used to Balance Out the Interference.

the receiving apparatus which is in bridged relation with respect to the line. However, in practice the two sides of the line are not exactly alike, so that some unbalanced results and a current is permitted to flow through the bridged receiving apparatus owing to a difference in the two interfering potentials on the two sides of the line.

In the present method it is proposed to balance out the interference by obtaining a current derived from the interfering potentials impressed upon the two sides of with the previous method of interference elimination.

The interfering radio frequencies from a distant radio station may be impressed upon both the high-frequency lines HFL and HFL′ and will be transmitted to the individual receiving channels of each line which have assigned to them a range of frequencies corresponding to the interfering frequencies.

These interfering frequencies are impressed in parallel on the two sides of both high-

frequency circuits, as for example the high-frequency line HFL, but due to unbalance of the two sides of the circuit a series component results which will be transmitted through the transformer 10 to the corresponding receiving channel to produce the interference above referred to. In order to balance out this component an inductance comprising a winding 11 is bridged across the carrier terminal circuit of the high-frequency line HFL, this winding having a very high impedance so as to produce but very little shunting effect with respect to the series carrier frequencies transmitted over the line HFL when used for ordinary wired-wireless transmission purposes. A tap 12 is taken from the midpoint of the inductance 11, and as the two halves of the inductance oppose each other with respect to the tap 12, it will be apparent that the disturbing potentials flowing in parallel from the two sides of the circuit HFL will pass into the tap 12 without being materially impeded by the inductance 11. The tap 12 includes a winding 13 inductively related to an inductance 11′ bridged across the carrier circuit associated with the line HFL′ in a manner similar to that of the inductance 11 already described.

The phase angle and amplitude of the currents flowing in the tap 12 may be controlled by the phase-shifting device 14 and the adjustable resistance 15 respectively, so that the currents flowing in the tap 12 may be adjusted as regards phase and amplitude so as to impress upon the carrier terminal of the circuit HFL′ through the inductance 11′ a potential equal in amplitude but opposite in phase to the disturbing component from the distant radio station. Similarly, by means of a tap 12′ from the midpoint of the inductance 11′ and leading to ground through a coil 13 inductively related to the inductance 11, the disturbing components flowing over the sides of the line HFL′ in parallel may be impressed upon the carrier circuit of the line HFL in series to neutralise the series disturbing component impressed upon the latter line. A phase shifter 14′

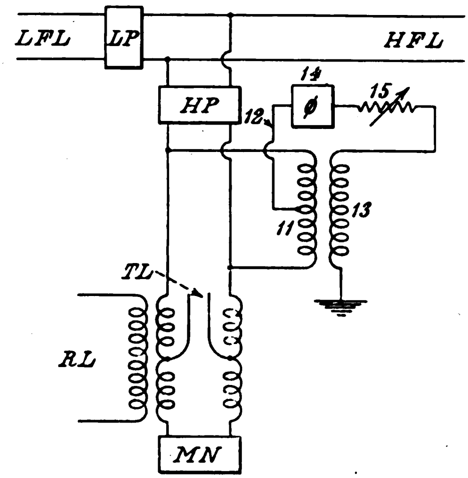


Fig. 8.—An Alternative Balancing System.

and an adjustable resistance 15′ will, of course, be used to obtain the desired phase and amplitude for the balancing potentials.

Instead of using potentials obtained from one line to balance out disturbing potentials upon another line, the balancing potential may be obtained from the disturbed line itself in the manner indicated in Fig. 8. In this case the ground tap 12 is taken from the midpoint of the inductance 11 as before, but it is connected to the coil 13 inductively associated with the inductance 11 of the same line, instead of a coil, associated with an inductance of another line. The disturbing components flowing in parallel over the sides of the line HFL will pass into the

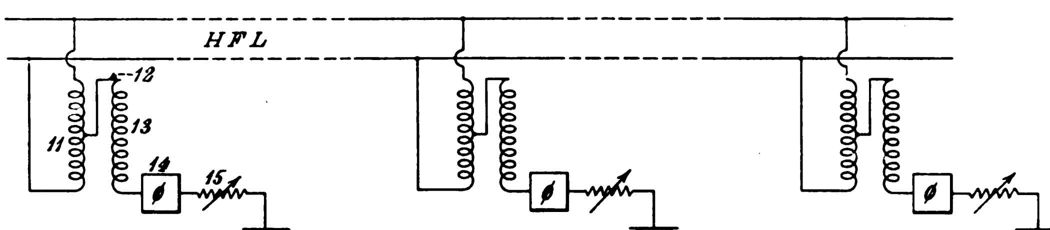


Fig. 9.—The Use of Compensating Devices at different Points along a Line.

ground tap 12 without producing any effect upon the inductance 11 which is balanced with respect to the parallel components. These components, in passing through the ground tap, will be adjusted as to phase and amplitude by the devices 14 and 15, and will then be impressed through the primary 13 upon the inductance 11 in such a manner as to cause a series component in the carrier branch of the line HFL. This series component will, of course, be adjusted to balance out the disturbing series component due to unbalance between the two sides of the line HFL.

Instead of arranging compensating devices at the terminal station, such devices may be located at different points along the line as indicated in Fig. 9 for the purpose of balancing the disturbing potentials before transmission to the terminal station. Each of the compensating circuits in Fig. 9 may be similar to those shown in Fig. 8 comprising a bridged inductance 11 with a tap 12 taken from its midpoint and leading through a primary 13 inductively related to the inductance 11 and also through a phase shifter 14 and through amplitude changing devices 15.

The Screening of Radio Receiving Apparatus.

By R. H. BARFIELD, M.Sc., A.C.G.I.

WIRELESS experimenters cannot advance very far at the present time without encountering the necessity for screening in some form or other. Possibly they will first meet with the problem in connection with multi-stage amplifiers for which judicious screening offers a means of obtaining increased stability by avoiding unwanted retro-action. Later, if they take to more serious work they will wish to make measurements in connection with the various phenomena which they observe. They will then find that it is often necessary to ensure that all parts of their circuits, save the aerial or receiving loop, are screened from the direct action of the waves. Finally, should it be necessary for them to instal their apparatus in the neighbourhood of conducting objects, such as metal buildings, electric cables or wires, etc., they will wish to know to what extent such things will affect their instruments and will therefore be interested in screening from yet another point of view.

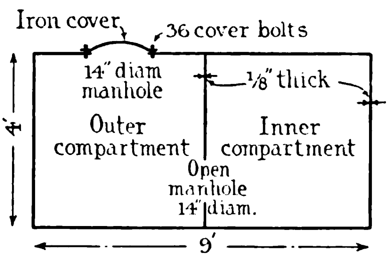


Fig. 1.—Iron Tank used in the First Experiment.

The object of this article is to describe some experiments on screening* which bear on these problems and to discuss the results from a simple theoretical point of view and thus to draw conclusions which it is hoped will be of use to those engaged in wireless experimental work.

Principles Underlying Screening Action of Conductors.

The simplest way of screening a piece of apparatus from electric waves is to place it inside a metal box so that it is totally enclosed. For owing to the well-established fact that good conductors are practically opaque to wireless waves, it is clear that by making the sides of the box thick enough and entirely free from cracks or other openings, the protection of the interior can be brought to any desired degree of perfection.

Though perfect screening can only be attained in the manner described above, it may be said in general that any conductor

* The experiments here described constitute a selection of those of most general interest from a detailed investigation of screening phenomena. See *Journal Institute of Electrical Engineers*, Vol. 62, No. 327, pp. 249-264, March, 1924.

or system of conductors has a screening action in its immediate neighbourhood. For, when a conductor is acted upon by the alternating fields which constitute a wave, currents are set up in it which create by induction secondary fields in its neighbourhood. Thus at such points we have two fields existing at any instant: (1) the main field as it would be in the absence of any screen, and (2) the secondary field due to the currents set up in the screen by the main field. A little consideration will show that in general, with waves much longer than the dimensions of the conductors employed, these two fields are in opposition, so that the resultant of the two fields is less than the main field. It is this fact which constitutes the screening action of the conductor.

This is indeed the simplest way of regarding all kinds of screening, including that of the closed box already referred to in which particular case the secondary field inside the box is almost exactly equal in magnitude to the main field so that the resultant field is almost zero. Although, as will now be seen, the principles underlying the screening action of a conductor are extremely simple, it is generally a comparatively difficult matter to calculate the exact effect of a screen of given construction. The experiments about to be briefly described were therefore carried out for the purpose of finding out the effects of screens of various simple kinds obtaining as far as possible actual measurements. It is thought that the results have brought to light some interesting facts and moreover are very suggestive of possible new commercial uses for some of the screens experimented with and, further, that a field has been opened up for some further experimenting on the same subject.

Wireless Receiver in Tank.

In this experiment a wireless receiver consisting of a frame coil and multi-stage amplifier was set up inside an empty oil tank, as shown in Fig. 1. The tank was provided with a single opening just large enough to admit the operator and the frame coil which, however, had to be collapsible for the purpose. The interior of the tank was divided into two compartments by means of an inner partition also provided with a small opening.

In the outer compartment and with the man-hole open, the operator, with his set, was able to pick up signals from Paris (spark) and also from a small tuned buzzer situated close to the tank and outside it. The manhole cover was then put in place and screwed on by means of 36 bolts round its circumference. Signals from Paris could be picked up until the last of the bolts was in place when this station was no longer audible but

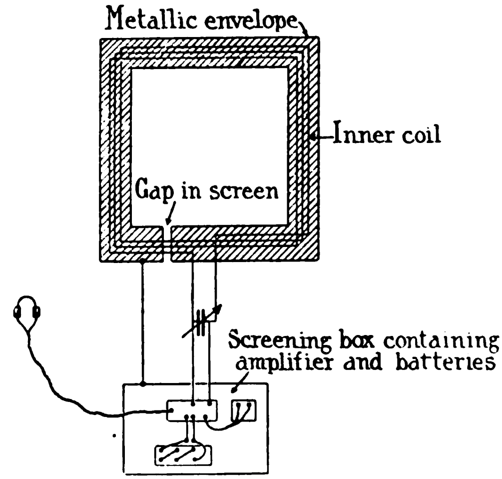


Fig. 2.—Screened Loop showing Gap.

signals from the buzzer could still be heard at good strength. When, however, the operator with the complete set retired into the inner compartment, neither buzzer nor signal of any kind could be picked up even though both manholes were left open.

Although perhaps this experiment may be considered rather crude it emphasises at least two important points with regard to screening in general, the first being that it is extremely difficult to close up an opening in a screen so as to prevent the entrance of energy, for there is no doubt that all the energy detected inside the tank must have passed through the imperfect joint between the cover and the tank, while the second is that the most effective way of attaining a high degree of screening is to employ a screen within a screen, as in the latter part of the experiment, when the screening was apparently perfect.

Receiving Loop with Screened Sides.

The next experiment attempted was one of considerable interest; the sides of a frame coil 2′ 6″ square were completely encased in a metallic envelope

made of tinned iron and in the form of a pipe of rectangular section (about 6″×3″). The leads from the coil were brought through two small holes in the envelope and connected to a sensitive amplifier contained in a metallic box. With the coil so screened, as was indeed expected, no signals whatever could be picked up. The envelope was next sawn completely through at the centre of one of the sides as shown in Fig. 2, a piece of wood being inserted in the gap to prevent the two ends from springing together and thus making contact. When the coil was again tested it was found to be quite an efficient receiver and stations many hundreds of miles distant could be picked up. A rough measurement showed that its efficiency was at least 50 per cent. of its normal amount. The size of the gap could be varied from the smallest obtainable crack to a width of several inches without any alteration in the strength of signals. Since only an entirely inappreciable amount of energy could penetrate the envelope itself, it is clear that practically all must have

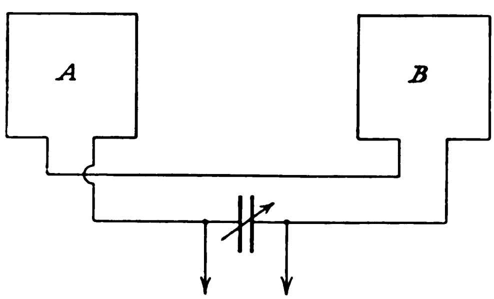


Fig. 3.—Method of Measuring Effect of Screen.

passed through the gap in order to get to the coil within—a further instance of the extreme importance of avoiding cracks in screens.

Unexpected as this result appears at first sight, a logical application of the simple principles of screening will be found to predict it. For, considering the case of any unscreened loop receiver we know that the signal strength obtained is proportional to the amount of magnetic flux due to the wave which links with the coil. To screen such a coil then it will be necessary to arrange a conductor so that the currents set up in it by the wave produce a secondary magnetic field in opposition to the main field and as nearly as possible equal to it in strength. Now a simple calculation shows that the envelope, forming a continuous circuit round the coil as in the first arrangement, will produce just such a field, but if we interrupt the continuity of the screen by a gap as in the second case the currents in the envelope and therefore the secondary field will drop to a negligible amount and there will therefore be no screening. The theory, then, is in entire agreement with the experiments. Nevertheless it must be admitted that it does not in this simple form give a satisfactorily physical explanation of the phenomenon as it is still not clear how the energy gets through the gap.

Method of Measuring the Effect of Screens.

In order to measure the effect of various screens a very simple apparatus was devised. This consisted of two frame coils A and B, connected so as to oppose one another as shown in Fig. 3, but so separated as to avoid any mutual interference; one of these coils (A) could be fixed either outside or inside the screen under investigation, while the other (B), which was made to rotate on a vertical axis and provided with a scale and pointer, remained outside.

In investigating a given screen the system was first tuned to some suitable transmitting station, then by rotating the coil B in the manner of a direction-finding coil, a position was found between its maximum and minimum setting for which, owing to the mutual opposition of the two coils, the signals were reduced to zero. This operation was performed twice with the coil A first unscreened and then screened and the angle (β) made by the coil B with the direction of the transmitter was noted in each case. Then remembering that the amount of magnetic flux linking the coil B is proportional to cos β, the amount by which the screen reduces the magnetic field within it can be easily obtained for it can be shown that :—

$$\frac{H_2}{H_1} = \frac{\cos \beta_2}{\cos \beta_1}$$

where H_1 and H_2 are the field intensity outside and inside the screen respectively and β_1 and β_2 are the corresponding angular positions of the coil B at the balance positions. This method proved very accurate and reliable and by means of it the effect of several kinds of screen were investigated.

Effect of Screen of Straight Wires and Open and Closed Loops.

To facilitate the experiments a light wooden frame work in the form of a cube of 6′ side was constructed to serve as a support for the various screens to be investigated. In the first place the four sides of the cube were covered with parallel vertical wires spaced 1″ apart and with their ends left free as shown in Fig. 4. By applying the method of measurement described above this arrangement was found to have no effect whatever on the magnetic field within it.

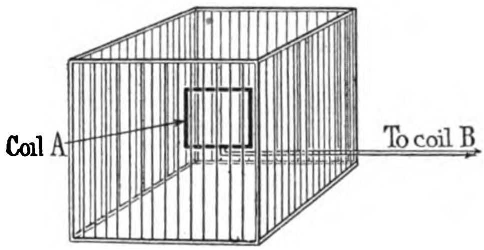


Fig. 4.—Screen of Short, Straight Wires.

Horizontal wires were now stretched across the bottom face of the frame and connected at each end to one of the vertical wires, thus joining two of the opposite faces, the remaining two being left as before. The screen therefore now consisted of a series of conductors of the type shown in Fig. 5 (*a*). This again was found to have no screening effect. Wires were now added on the top face but in the first place were only joined at one end to the vertical wires so that the cage was now composed of conductors as in Fig. 5 (*b*) (*i.e.*, of " open " loops), but still no screening effect was detectable.

The gap in each loop was next closed so that a screen of closed loops (as in Fig. 5 (*c*)) was obtained. A marked screening effect was now noticeable which was a maximum when the plane of the loops was aligned on the transmitter but zero when at right angles to this direction. In the position of maximum screening the field within the cage was found to be about 1-10th of its value outside. That is to say, 90 per cent. of the intensity of the magnetic field had been cut off by the screen. This percentage has been named the screening ratio of the screen as it is thought that this value most clearly expresses its screening properties.

On reducing the number of loops forming the screen the screening ratio was found to fall off rapidly at first and then more slowly as the intervals between the wires became very large. This is shown in the curve in Fig. 6, in which the spacing of the loops is plotted against the screening ratio. It appears from this curve that if the spacing were made still closer than its original value (about $1\frac{1}{2}''$) the screening ratio could be made to approach very closely to 100 per cent.

These experiments demonstrate very clearly that to screen the magnetic field of wireless waves it is essential to employ a screen containing closed circuits, that is to say, the screen must be so constructed that currents can flow uninterruptedly round its exterior in all directions. If the screen is to be non-directional the current must be able to circulate in all directions.

Suggested Use for Screen of Closed Loops.

The directional properties of the screen of closed loops arranged in parallel planes which were demonstrated in the preceding experiment suggest that such a screen might have a practical use at a wireless station which wished to receive and transmit simultaneously on one wave-length. For, if, as shown in Fig. 7, the receiving frame coil were installed inside a multi-loop screen of which the loop planes were directed accurately towards the home transmitter while the site of the screen was so chosen that the direction of the distant transmitter was nearly perpendicular to the loop planes, by careful orientation of the loops and by employing close enough spacing the receiver so installed could be protected to any desired extent from the home transmitter while

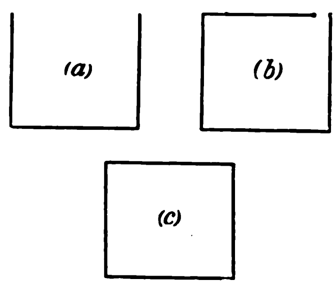


Fig. 5.—Conductor " Elements " of some Screens Experimented with.

signals from the distant transmitter would not be affected at all. Such an arrangement, in fact, should certainly prove a valuable addition to existing interference-preventing

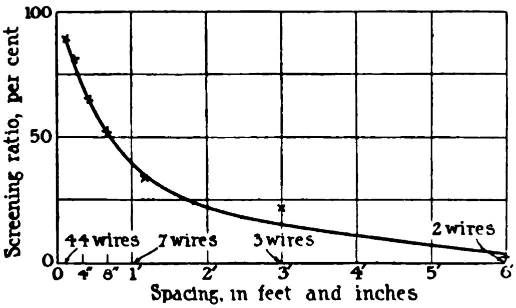


Fig. 6.—Variation of Screening Ratio with Spacing of Closed Loops.

devices as employed in such cases even if not sufficient in itself.

Screening Effect of Wire Netting.

In the next series of experiments the framework was covered with wire-netting, first of two-inch mesh and then of one-inch mesh, so as to form a closed box or cage. No gaps were left and all the seams were bound together with copper wire so as to make joints of good conductivity. The measurement of the screening effect was made in the same way as before—a temporary opening being made in the side of the cage in order to admit the coil A when necessary. The screening ratio was found to be 89 per cent. for the two-inch mesh and 96 per cent. for the one-inch for a wave-length of 4·5 km. The experiments were repeated on different wave-lengths ranging from about 0·5 to 7·0 km., and a definite decrease in the screening ratio with increase in wave-length was observed but so small as to be unimportant over the range of commercial wave-lengths. Since a screen of this kind is symmetrical its screening properties should not vary with the direction of arrival of the waves and this point was verified by experiment. The effect of the cage at points outside it was also investigated, and it was found that when the distance away exceeded the dimensions of the cage its effect was negligible.

In order that the screening properties of the various screens described may conveniently be compared a table is given above in which the screening ratio of each of them is recorded.

Comparison of Screening Properties of Various Screens.
(Magnetic Field.)

Type of Screen.	Screening Ratio.
Screen of straight wires (Fig. 4)	0%
Screen of open loops (Fig. 5b)	0%
Screen of closed loops (perpendicular to direction of transmitter)	0%
Screen of closed loops (parallel to direction of transmitter)	90%
Screen of wire-netting 2" mesh	89%
Screen of wire-netting 1" mesh	96%

Practical Use for Wire-Netting Screen.

The preceding experiment shows that wire-netting is capable of making a screen quite effective enough for many purposes. For this reason it has since been employed to screen a Bellini-Tosi direction-finding set from "direct pick-up." That is, to prevent the amplifier and its associated circuits from picking up energy from the waves independently from the aerial loops. Since it was essential for the operator to be within the screen, the walls, floor and ceiling of the hut containing the apparatus were lined with wire-netting of 1" mesh, great care being taken to ensure that good contact was made at the seams. The result was very satisfactory, for after the installation of the screen it was found that no direct pick-up whatever could be detected whereas before its erection it was possible to obtain signals of considerable strength from low power stations hundreds of miles away with the aerials entirely disconnected. The use of wire-netting for a purpose of this kind entails the

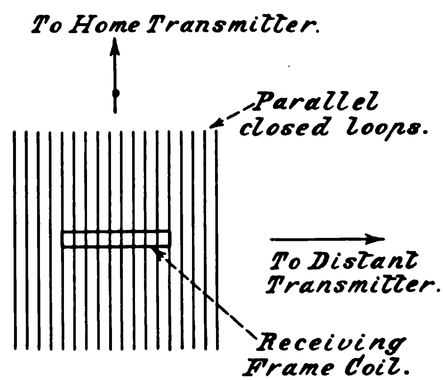


Fig. 7.—Directional Screen arranged to Protect Receiver from Local Interference.

advantage that it is inexpensive, and unlike solid metal sheet, does not interfere with ventilation or lighting.

Screening of Electric Field.

It has already been pointed out that the method of measurement employed in the preceding experiments deals only with the magnetic field. The investigation was therefore not complete without some examination of the effect of screens on the electric field and this was accordingly carried out, though not in such a detailed manner as the first part of the investigation. Summarising the results briefly it was found that the screens of straight wires (Fig. 4) and of open loops (Fig. 5 (*b*)) which had already been found to be without influence on the magnetic field (see Table) had a considerable screening effect on the electric field, the screening ratios being 80 per cent. and 94 per cent. respectively. The effect of the closed loop and wire-netting screens was not measured.

The fact thus demonstrated that a given screen may cause a large reduction in the electric field of a wave without affecting the magnetic field is of some considerable interest

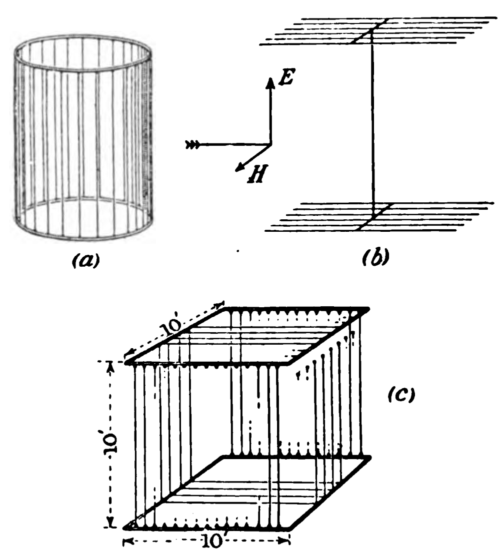


Fig. 8.—Screens which Reduce Electric Field of Waves without Reducing Magnetic Field.

since we know that outside the screen the two fields are always exactly equal. It will be found, however, that it is quite in accordance with the simple theory as outlined at the beginning of this article, for in screens which have this property the electric induction field is of the same order as and in opposition to the main "wave" field while the magnetic induction field is negligible owing to the absence of closed circuits which alone can produce such a field. Three types of screen having this property of screening the electric field without affecting the magnetic field are illustrated in Fig. 8;

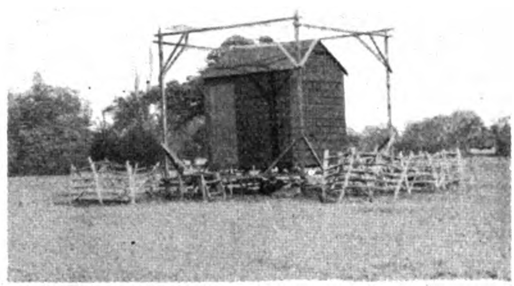


Fig. 9.—Open Loop Screen Erected Round Hut containing D.F. Apparatus.

two of them (*a*) and (*c*) have already been described. Such screens have since been applied very successfully to solving one of the problems of direction finding, namely, that of eliminating the source of trouble known as "antenna" effect. This effect, which causes errors and flat minima in direction finding sets, is due to the action of the electric field of the waves on the directional coil and its associated circuits. Consequently, if the apparatus be placed entirely within a screen which protects it from the electric field "antenna" effect must necessarily vanish; while at the same time if the screen has no effect on the magnetic field of the waves the receiving properties of the directional loop will be unimpaired.

This device has now been put into successful operation as an anti-"antenna" effect screen for a direction finder of the single-coil type which is being used for making accurate observations. The coil has been erected inside a screen of the open loop type (Fig. 8 (*c*)). The exterior of the installation is shown in the photograph (Fig. 9) in which the screen can be seen surrounding the hut containing the apparatus. It will be noticed that the hut is insulated from the earth by means of four large insulators placed under each of its four corners.

A Universal Meter.

By H. E. DYSON.

Very little useful experimental work can be accomplished without the aid of measuring instruments. Below will be found details of a universal instrument which can be made quite cheaply from the simplest of materials.

THE amateur is often, and wisely, urged to forsake rule-of-thumb methods, to measure all his quantities, and thereby become a useful member of society. Undoubtedly the value of experimental work is enormously increased by the taking of accurate measurements. The most convenient way to ascertain current and voltage values is to purchase a good range of high-grade meters. A cheaper way is to purchase one instrument having a number of ranges, though this sometimes necessitates changing the meter from one part of a circuit to another during an experiment.

It may be taken that the ordinary small pocket voltmeter or ammeter of the soft iron type is not usually very accurate, and also the energy required to operate them often entirely alters the conditions in the circuits to which the experimenter applies them.

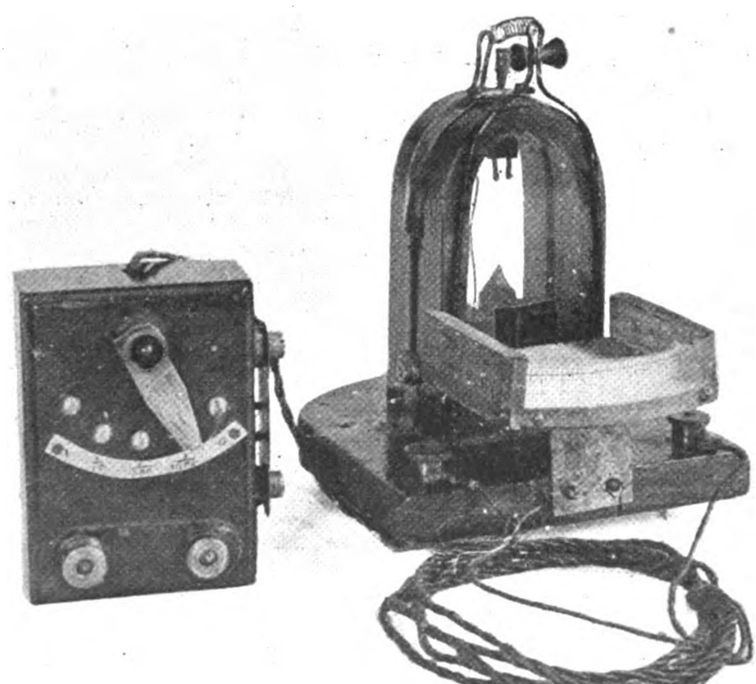


Fig. 1.—A General View of the Instrument and Shunt Box.

The amateur who cannot afford high-grade instruments need not, however, despair. A moving coil instrument of the suspended type is not at all difficult to make and requires no lathe or special tools. It can be used with a home-made shunt, which will enable measurements to be taken with sufficient accuracy for all ordinary purposes, down

to a milli-volt, and small fractions of a milli-ampere, and up to any current or voltage that may be required. Owing to the even scale of this type of instrument, and to the fact that a "universal" shunt is employed, it is only necessary to obtain one point in order to calibrate the instrument. A standard cell and a 1,000-ohm resistance may be purchased from any large electrical firm. An ordinary Leclanché cell may be used as a sufficiently good standard for ordinary use, of less than a thousand ohms, nor for more than thirty seconds. The zinc must be kept quite smooth and clean. The voltage will then be 1·47. With the known voltage and known resistance it simply requires the use of Ohm's law to obtain the voltage or current for a given deflection of your meter. The scale being perfectly even, it is again a matter of simple proportion to fill it in. The shunt box being arranged in steps of 10 to 1, the same instrument serves for

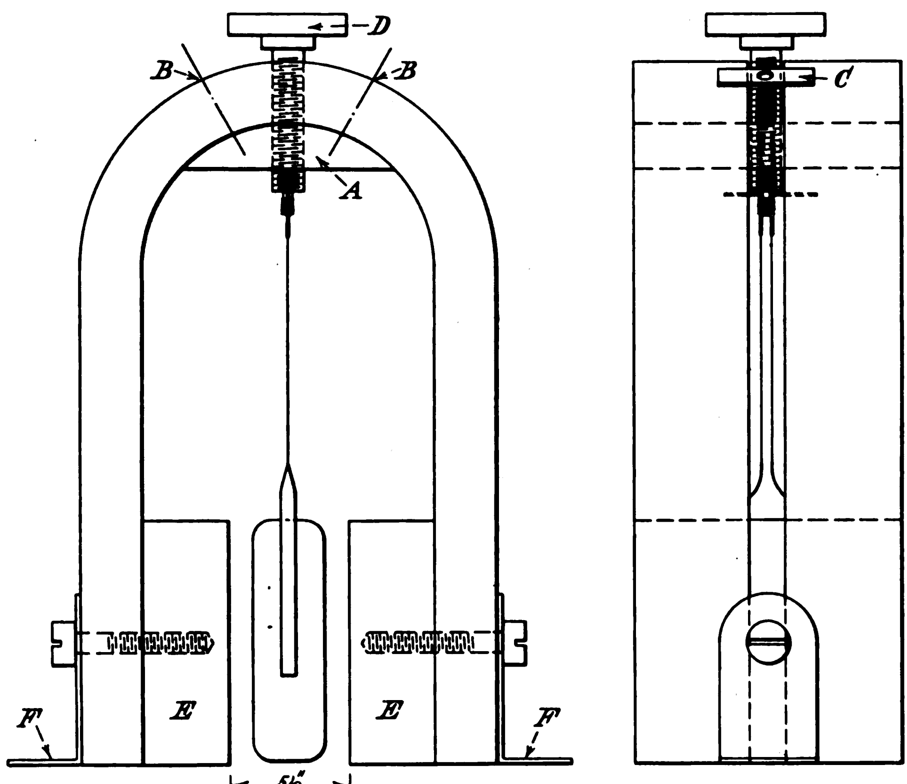


Fig. 2.—General Assembly of the Instrument.

providing certain conditions are rigidly adhered to.

The cell must be new when taken for use as a standard. The solution must be 1½ ozs. of ammonium chloride (sal ammoniac) to the pint of water, and water must be added from time to time to keep the solution level and, therefore, its density constant in spite of evaporation. The cell must not be used for any other purpose than the calibration of your meter, and never closed by a circuit currents much larger or smaller than that used to calibrate the instrument.

The essential parts of the meter are shown in Fig. 2. A coil is suspended between the poles of a powerful magnet by two fine parallel wires (No. 47), or two strips of the thin phosphor bronze sold for this purpose. Current is led down one strip to the coil, and back again along the other. The coil bobbin is made of wood, as this is lighter than most insulating materials. If a good hard wood is

chosen the groove for the wire 3-16th" wide and ⅛" deep can be easily filed in it (Fig. 3). The most useful gauge for general work is about No. 44 enamelled wire.

A strip of copper foil is cemented on each side of the bobbin with hot shellac (not shellac varnish). To these are soldered the two ends of the coil, and also the two suspension wires or strips. A pointer of copper wire or other non-magnetic material is inserted in a hole in the bobbin and fixed with hot shellac.

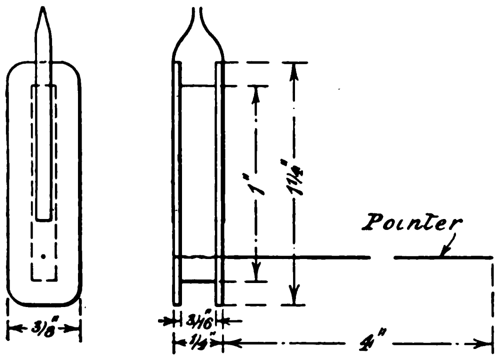


Fig. 3.—Details of the Moving Coil.

To carry the top screw D of the suspension system a fixed piece of ebonite A, having its upper surface filed to fit the magnet, is fixed in position by two screws at B, B. These pass between the two magnets and through the strips of brass C. The end of the suspension screw D is shown enlarged in Fig. 4. The end of the screw is reduced by turning or filing to enable the suspension wires to be brought closer together. Two No. 36 double silk covered wires are fastened to this reduced end by hot shellac. The end can then be bound with silk and varnished. The top end of the suspension wires are soldered to these. The No. 36 wires on the screw and the copper plates on the bobbin should be bent to hold the suspension wires parallel and about 1-32nd" apart. The No. 36 wires are also connected by fine wires to the terminals of the instrument. An alternative method is shown in the photographs, an ebonite block being fitted to the end of the screw and two small screws inserted. The suspension wires are then soldered to these. The purpose of the screw D is to enable the user to adjust the pointer to zero. It will be convenient to use No. 2 B.A. rod, and then an ordinary condenser knob on top, instead of the lever adjustment seen in the photograph.

The magnets from ordinary telephone magnetos are very suitable for providing the magnetic field, and at the present moment a large number of ex-Government magnets are being sold very cheaply.

The use of two enables screws to be passed through the narrow gap between them, and thus avoids the necessity for softening, drilling, re-hardening, and re-magnetising them.

The two like poles must, of course, be placed on the same side. Two iron blocks E, E are used to reduce the air gap. Dimensions of these parts are not given, as they must be made to suit the particular magnets which may be obtained. The same screws which hold the blocks and magnets together also hold the two angle pieces F, F which are used for fixing the instrument to its wood base.

An ivorine condenser scale forms quite a good scale if screwed on the base under the pointer. Only about two-thirds of the scale will be required.

The instrument must be protected from draughts either by placing it in a glass case or by covering the ends of the magnets and the space for the pointer with thin celluloid, as in the instrument photographed.

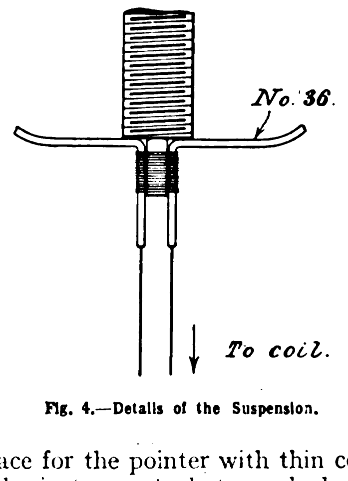


Fig. 4.—Details of the Suspension.

The coil as well as the scale must be clearly visible in order that it can be seen when it is swinging properly clear of the magnet poles.

The wire frames at the ends of the magnets hold the celluloid ends on. These go

into holes in the base and at the top are held together by a spring from one to the other.

This instrument has also been fitted with an edge scale, this being the most convenient form of scale when the instrument is on a bracket on the wall. It is absolutely essential that the meter should be fixed where it will

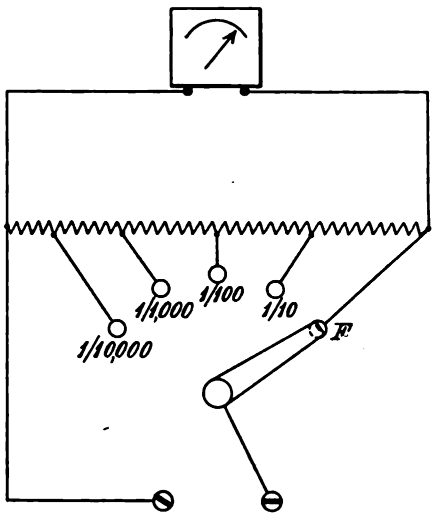


Fig. 5.—Arrangement of the Shunts.

not be subject to vibration, and fixing on the wall is generally the best method of obtaining this result.

The scale is made with Indian ink on white card, and afterwards bent to the required arc and glued in the small box made for it. The pointer comes over the top edge of the scale, and is bent down in front of it. The tip of the pointer is also fitted with a piece of card soaked in red ink so that an approximate reading may be obtained from the opposite side of the room. In using a scale of this kind two methods of dividing it are available—one to mark it in degrees, the other to mark it when the instrument is ready for calibration in milli-amps or some other suitable division of an ampere or volt. The first method requires more calculation in taking a reading, but involves no difficulty if at any time the instrument alters its " constant " or sensitivity.

The insulation to earth should be very high, but that across the coil is unimportant, as the voltage across it will always be extremely low. The desired result can be obtained by mounting the wood base on three ebonite feet.

The instrument will be ballistic when used with a shunt box. All ordinary measurements will be made with the shunt box in use, and the instrument will then be dead beat. Its great sensitivity enables very low resistance shunts to be used when measuring current, and for measuring volts the full shunt resistance for damping purposes in conjunction with very high series resistances. Thus they consume very little energy, and rarely affect the circuit conditions. Large currents such as the filament current of a valve, or the charging current of the accumulator, can often be measured by considering the instrument as a voltmeter, and connecting it across several inches of the leads. If these are a known gauge of copper wire, an ordinary

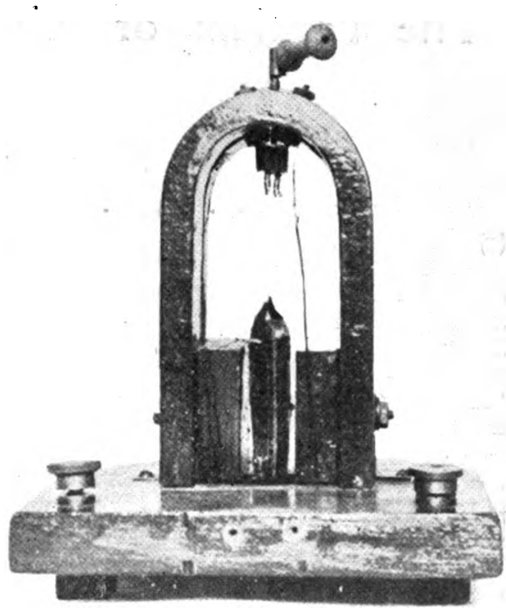


Fig. 6.—Rear View showing Pole Pieces and Coil.

rule and a table of resistances will give the resistance of the length used as a shunt, and Ohm's law gives the current.

The shunts in general use can be placed in a box about six inches square by two inches deep with the switch mounted on top and connected as shown in the diagram. The usual wireless switch parts should be used for this (the instrument illustrated was made

before these were so readily obtainable), and ebonite used for the top. Care must again be taken that the insulation to earth is extremely high.

If the shunt ratios are to be 1 : 10, 1 : 100, etc., the switch must reduce the resistance between the terminals to 1 : 9, 1 : 99 and so on of the total shunt resistance. About No. 30 of any good brand of high-resistance wire will be suitable for the shunt resistances, and if one gauge is used throughout the correct quantities can be measured off. The total resistance can be obtained approximately from resistance tables for the resistance wire used. Its value does not affect the accuracy of the shunt box. It is the ratios which must be kept as correct as possible. The total should preferably lie between 20 and 200 ohms. The lowest values should have several strands in parallel. The instrument will give its own resistance either used alone or with any value of shunt if a known standard resistance is available.

The writer's instrument gives one division on the scale for 1-50th of a milli-amp, and gives four divisions per amp. when shunted by 1·32" of 18 gauge copper.

The meter works, of course, on direct current only, but is eminently suitable for operating with a thermo-couple for alternating currents of any frequency.

The Problem of High-Tension Supply.—II.

By R. MINES, B.Sc.

(*Continued from June issue, page* 531.)

Use of an A.C. Supply.

(1) *Transformers.*

As has been stated in our introduction, an alternating supply may be changed into a supply at a different pressure by means of a transformer. This is a very simple and reliable method, for a transformer is essentially nothing more than two inductive windings coupled with an iron core. There is also every facility nowadays for obtaining trustworthy apparatus, for quite a few firms of repute in the electrical industry manufacture small power transformers specially for supplying wireless apparatus. An output of 2,000 volts on the secondary is a standard rating, and these same transformers can be supplied with a low-tension secondary to supply filaments when valve rectifiers are to be used; this winding is, of course, brought to separate terminals, and is highly insulated.

One may say that this part of the "problem" of using an alternating supply for deriving the high-tension power is easy to solve.

(2) *Rectifiers.*

An electrical rectifier may be sufficiently defined as an apparatus that will allow current to flow through it in one direction only when an alternating P.D. is applied to it. There are many different kinds of apparatus that can be used as rectifiers, each with its particular advantages and its special mode of operation; a detailed discussion of these different types will be given in a later section of this article. However, the definition given permits us to consider how we may use our rectifier.

(*a*) We have an alternating supply, either alone or through a transformer, chosen to give the correct pressure; the problem is to derive a unidirectional supply from this. The simplest plan, using a single rectifying apparatus (denoted by R) is shown in Fig. 1 (*a*). Here the alternating supply is connected up to the high-tension terminals with the rectifier in series. Let us suppose that by using a "reservoir condenser," or other means, the potential difference (P.D.) between the high-tension terminals X, Y is maintained constant; then our supply of power to the circuit connected behind these terminals must consist in pumping current into the circuit against the steady P.D.

Now in Fig. 1 (*b*) curve (i) shows the

alternating P.D. which is to be utilised, and curve (ii) represents the steady P.D. on terminals X, Y. Curve (iii) shown in Fig. 1 (*c*) is the difference between these two, and represents, therefore, the P.D. available for pumping current into our high-tension circuit. The portions N H M′, etc., of this curve (iii) represent the P.D. across the rectifier in such a direction that no current is allowed to flow; the portions K M N, K′ M′ N′, etc., of the curve represent the P.D. across the rectifier in such a direction as to allow current to flow, and current will, therefore, flow through the rectifier and into the high-tension circuit, according to some curve such as (iv).

It will be noted that this current flow takes place in "pulses," a heavy current flowing for a small fraction of each cycle of the alternating supply and nothing happening in the interim. We shall see under the heading of "Filters" that this is an undesirable condition and involves considerable additional apparatus if the power supply to the high-tension circuit is to be maintained constant with respect to time.

(*b*) It is possible, however, to improve this state of affairs, and provide two pulses per cycle. It is necessary now to use two rectifiers (R_1 and R_2), and either two transformers or a mid-point tapping must be available, in order that the two rectifiers may be subjected to P.D.'s in opposite sense, and their contribution of current so made to alternate with each other, instead of to coincide. Fig. 2 (*a*) gives the connections and shows also the methods of using two separate transformers, or an auto-transformer, to supply the mid-point tap when the supply is being used direct. In Fig. 2 (*b*) curves (i) and (ii) represent the alternating P.D.'s of the two sides of the alternating supply, while curve (iii) is the steady P.D. as before. Fig. 2 (*c*) curves (iv) and (v) are the P.D.'s on the rectifiers 1 and 2 respectively, and curve (vi) shows the resultant current flowing into the high-tension circuit.

This method is described as "full-wave rectification" (the first being known as "half-wave rectification") because it utilises both the positive and the negative pulses of the alternating supply.

The obvious disadvantage of this arrangement is the necessity for the use of a mid-point tapping, which involves insulation difficulties on a high-tension secondary winding, or the use of two separate transformers instead of one. Again, supposing the same transformer apparatus to be used in each case, this method of connection enables the D.C. supply to be maintained against a P.D. which is only half of that possible if the connections of Fig. 1 (*a*) were used. The current pulses have been doubled at the expense of halving the pressure.

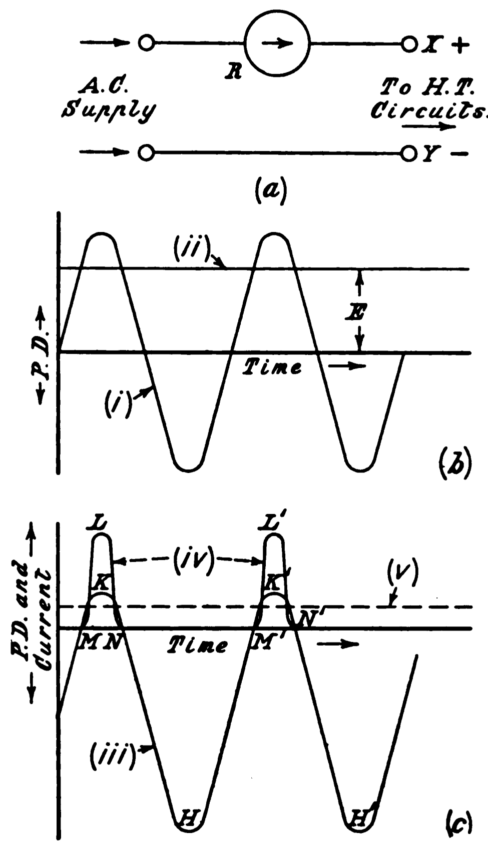


Fig. 1.—Illustrating the Effect of Rectification.

(*c*) An improvement on this method is shown in Fig. 3, which eliminates the need for a second transformer or a mid-point tapping. As will be seen, however, it requires four rectifying units instead of two (but this may be no disadvantage if it is found necessary to use banks of rectifiers, instead of single units).

The potentials acting in this circuit may be represented by Figs. 2 (*b*) and (*c*), as in

the previous case; the only difference being that the positive potential pulses M K N, M′ K′ N′ come across the two rectifier units R_2 and R_3 in series, and similarly the

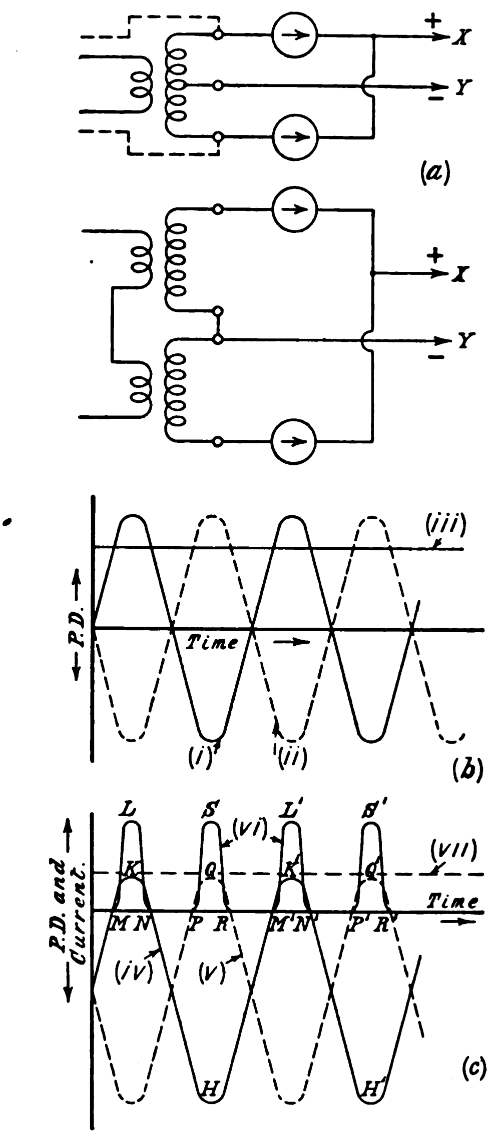


Fig. 2.—Two Pulses per Cycle are now Rectified.

pulses P Q R, P′ Q′ R′ come across R_1 and R_4 in series. Likewise, the current pulses in M L N, M′ L′ N′ pass through R_2 and R_3 in series, and the pulses P S R, P′ S′ R′ pass through R_1 and R_4 in series; therefore, if the rectifier units are of the same type and rating, the potentials will divide equally across the two in series; note, therefore, that each unit is called upon to deal with only half of the total potential drop.

It will be noticed also that with this method of connection (Fig. 3) the full D.C. pressure is obtainable, as with the first method (Fig. 1*a*), together with the double pulse of current.

(*d*) We will now describe a simple but ingenious method of connection used by Coolidge and Hull; this is shown in Fig. 4. The means employed for maintainance of the D.C. pressure are here shown as reservoir condensers. It will be noted that there are two condensers, C_1 and C_2, joined in series; the mid-point between them (which may be earthed if desired) may be regarded as a "mid-wire," so that the D.C. output is in the form of a "three-wire system," with one reservoir condenser across each half. This is the essential feature of the system. One lead from the alternating supply is connected to this mid-point, and the rectifiers (only two are required) are connected with the other alternating supply lead in such a manner that current pulses are pumped alternately into each side of the D.C. supply. The potential distributions and current pulses in this circuit are similar in nature to the previous cases.

Note that this method shows two improvements over the previous one—only two rectifiers are necessary, and the D.C. pressure available is doubled; while considering the D.C. circuit as a whole, the current pulses are injected still at double the frequency of the alternating supply.

(*e*) It will have been noticed as a characteristic of the above methods of generating high-tension supply that the delivery of current is not constant, but has a periodic variation ("pulses"). Reference to Figs. 1 (*c*) and 2 (*c*) shows that the maximum value of the current flow is represented by the ordinate at L or S. Now, the area of a pulse, M L N, for example, represents the quantity of electricity delivered at each pulse of current. The average rate of flow of electricity, which gives the value of the current supplied to the wireless apparatus if this current is held constant (as by a filter), is the product of this quantity per pulse and the frequency of the pulses. The pulses of

current occur during the periods of time M N, M' N', etc., which are less than half the time-period of the alternating supply; and, again, the current attains its maximum value for only a portion of each period M N, etc. It will be seen, therefore, that the average value of the current delivered by the converting system (shown approximately by curves (v) and (vii) of Figs. 1 (*b*) and 2 (*b*) respectively) is only a small fraction of the maximum value that flows. This point is of importance in choosing the size of rectifier that must be installed, for with some types (*e.g.*, the diode valve), the current rating is determined by this maximum value.

(*f*) We have noted also in our first article that the pressure delivered to our wireless circuit must be extremely "constant in value." It is obvious that the supply delivered in pulses as described above is of no use—but it can be "smoothed" to the required degree by means of suitable filter apparatus, details of which will be given in a later section.

(3) *Efficiency.*

There are two principal sources of loss of power in this method of producing high-tension D.C. supply. First is the loss usually occurring in a transformer, and needs no detailed description here; it will amount to

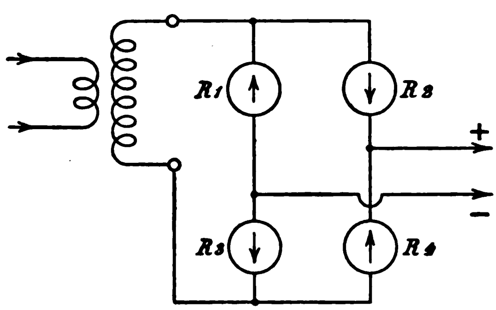


Fig. 3.—Full Wave Rectification.

only a small proportion of the power passing through even for this class of work.

The second seat of loss is the rectifier itself. We have seen, in the simple case shown in Fig. 1, for example, that the portions M K N, M' K' N', etc., of the P.D. across the rectifier are accompanied by the pulses of current M L N, M' L' N', etc., flowing through the rectifier, and the instantaneous product of these two quantities, P.D. and current, gives the power wasted in the rectifier at each instant. The average value of this loss is naturally the product of the average value of the P.D. and the average current, taken over a whole number of cycles. The amount of power wasted in this manner may be a considerable proportion of the amount of power passing through the system; but it can be reduced to a minimum by proper care in the choice of type as well as size of rectifier, to suit the P.D., current, and frequency that are to be used.

Use of a D.C. Supply.

(1) *Direct Connection.*

Provided the supply pressure is not less than the pressure required by the wireless apparatus, the problem is relatively easy of solution. In fact, if the pressure is suitable for the purpose in hand, all that it is necessary to do is to connect one's apparatus direct to the mains; except that in most cases it will be necessary to take the supply through a filter circuit, because the electricity supply, being generated by machines with commutators and armature teeth, will contain objectionable ripples that must be eliminated.

Needless to say, there are certain precautions that require attention:

(*a*) The correct polarity of the supply must be determined, and the connection made accordingly;

(*b*) There must be no independent earth connection (such as would be occasioned by a single-circuit tuner without an earth condenser) on the wireless apparatus that is to be supplied with high-tension power, because either the positive or the negative main may be at earth potential;

(*c*) Especial care should be taken to guard against accidents with the high-tension circuits, and in particular these should be connected to one point only of the valve filament circuit to eliminate the possibility of a short-circuit current using a valve filament as a fuse!

(*d*) In all probability sufficient protection to the high-tension circuits will be afforded by the fuses in the distribution box of the electricity supply, but if blowing this fuse puts out the light one is working by, separate fuses must be installed designed to blow out at a much smaller current.

(2) *Potential Divider.*

When the pressure of the supply is too high for direct use a portion of it may be tapped off by means of a potential divider. This consists essentially of a high-value resistance, connected across the mains, the output being taken usually from one of the mains (one end of the resistance), and a tapping point on the resistance (whose position is frequently made variable). The arrangement is shown in Fig. 5. Here A C is the high resistance, of value R ohms, and B is the tapping point; the portion of resistance B C will then be variable, and its value may be called x ohms.

Let E be the supply pressure, and e the pressure required by the wireless apparatus, both in volts. Then when no current, or a negligible current, is being drawn by the circuit connected to B C, the following relation holds:

$$E : e = R : x.$$

Therefore we can determine where the tapping point must be to give the required pressure e, for:

$$x = e \times \frac{R}{E}.$$

The effect of drawing a current from the points B C is to increase the potential drop in the portion of the resistance A B, and,

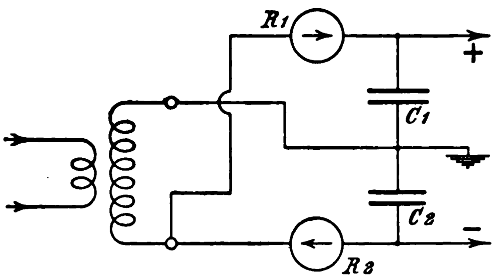


Fig. 4.—Full Wave Rectification by means of four Rectifiers.

therefore to decrease the pressure available across B C, *i.e.*, the value of e. This effect may, of course, be compensated by moving the tapping point B nearer to A, *i.e.*, by increasing x.

This method is rather wasteful of power, due to the fact that current is flowing through the resistance R independently of how much current is being drawn off for use by the circuit on B C. However, if one can determine exactly how much current (call it i amperes) is to be used, the arrangement may be modified. The portion of resistance B C may be omitted (*i.e.*, made infinite); then the current drawn from the mains becomes equal to i. The arrangement is now a simple series resistance. Care must be taken to proportion the value (say y ohms) of this resistance A B correctly, for it must drop all the surplus pressure with only the small current i flowing through it. In other words,

$$y = \frac{E - e}{i}.$$

The same remarks apply in this case as in the first, as regards the necessity of using a filter and the precautions to be taken.

Gayes' article in the November issue of EXPERIMENTAL WIRELESS may well be read at this point, for he gives useful tips concerning precautions mentioned in section (1); shows a convenient way of making connection to the supply mains without any disturbance of or addition to the wiring, and show a useful method of building up a potential divider, using low-power lamps as the resistances.

(3) *Electrostatic Transformer.*

There will be many cases, mostly where transmission or similar work is carried on, where the supply pressure is insufficient for use by itself. A favourite method of overcoming this difficulty is to use the supply pressure combined with some auxiliary supply connected in series. A small battery may be used when the deficiency in pressure is small; if larger, a generator ("booster") may be used, and this is a convenient method, for the generator may be driven by a motor running on the D.C. supply. Needless to say, there are a number of the methods to be described in these pages which may be used in series with the electricity supply. A case in point is the one described in the article "Transatlantic Radio-Telephony," which appeared in the March issue of this journal; in this case a generator of the "impulse type" (to be described later) is used in series with a 500-volt D.C. supply (which happens to be a secondary battery).

On the other hand, it may be better to convert the supply straightway to the desired pressure. The use of a motor-generator or a rotary transformer, or a battery system with units charged in parallel and discharged in series, are well-known

methods for accomplishing this result, but their description comes under other headings. The method to be described here involves a direct electrical conversion of the energy, without its appearance intermediately in a mechanical or a chemical form.

This electrical D.C. converter may be described as an "electrostatic transformer," since it performs the same function for a D.C. supply as the inductive transformer does for an A.C. supply. In its practical form the apparatus is the "D.C. Voltage Raiser" developed by Scroggie, and described by him in EXPERIMENTAL WIRELESS for February last. The method is to use a number of condensers, each charged successively from the supply mains by a motor-driven commutator and discharged continuously in series into the high-tension circuit (through a filter circuit of course). Owing to the finite capacity of the condensers there is a fluctuation of the output P.D. for each charge, and the capacity value required for each condenser to keep this fluctuation within specified limits may be determined from the formula :

$$C=\frac{I}{f.Ex}.$$

where C = Capacity of condenser in μF (microfarads);
I = Output current ma. in (milli-amperes);
E = Output P.D. in kv. (kilo-volts);
x = Fractional variation of output P.D.;
f = Frequency of charging of the condensers in cycles per second.

This is quoted to show that the condensers function similarly to "reservoir condensers."

The apparatus should prove to be a very efficient converter—perhaps some keen ex-

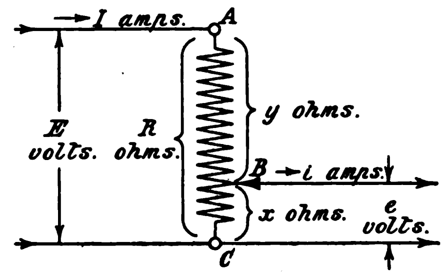


Fig. 5.—A Potential Divider.

perimenter who is using the apparatus will carry out tests and publish some figures for actual overall efficiency. There are three principal sources of loss :

(i) The power required to drive the commutator, including motor losses ; this is probably the largest item in small power apparatus ;

(ii) Electrical losses at the commutator, due to P.D. drop at the contact and to sparking ;

(iii) Dielectric losses, etc., in the condensers (these will be dealt with under "Reservoir Condensers" in the section on Filters).

(To be continued.)

The Design of Transmitting Valves.

BY G. L. MORROW.

Below will be found the fundamental principles underlying the design of transmission valves, which should be of great value to all engaged in transmission.

THE object of these notes is to describe as simply as possible the theoretical design of transmitting valves, knowing the power which it is proposed to use for its excitation and also the general type of characteristics which it is desired to obtain.

Whilst it is obvious that certain discrepancies are bound to exist between theoretical predicted values and those obtained in practice, it will be found that the methods of calculation employed for the various essential quantities will show a sufficiently close agreement with practical results for the purpose of this article.

Three important factors relating to the

probable behaviour of the valve as designed will be dealt with in detail as they arise. These are :—

(1) The anticipated life of the valve, *i.e.*, life of the filament.

(2) Whether the electrodes are liable to become distorted or even melted, or the vacuum destroyed by sudden overloading when working on the rated power.

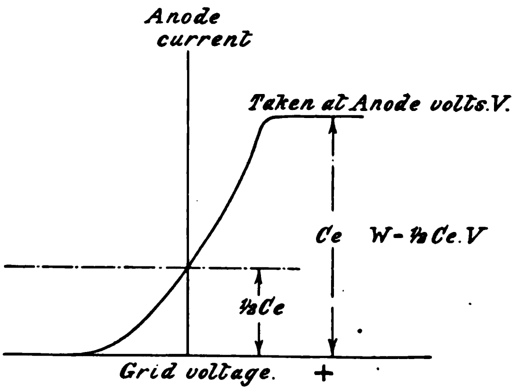


Fig. 1.—An Anode Current Grid Voltage Curve.

(3) Stability of operation.

The three factors given above are very closely bound up with the design of the valve itself, but the question of the probable transformation efficiency, namely, the proportion between the power expended in the oscillating system and the power drawn from the supply, is also dependent to a very large extent on the type of circuit employed, and will not be discussed in the present article except incidentally.

The order in which the various factors are dealt with is as follows :—

(*a*) The general consideration of the proposed form of power supply to the anode and filament in relation to the probable life of the latter. That is to say, the operating temperature of the filament.

(*b*) Arising from (*a*) the design of the filament.

(*c*) The choice of the general form of the anode current—grid volts characteristic of the valve.

(*d*) The design of the anode in order that it may be capable of dissipating the necessary power without overheating.

(*e*) Arising out of (*c*) the arrangement of the filament system and the closeness of the grid to give the required characteristics.

(*f*) The detail design of the grid.

Certain other important factors in the design of a transmitting valve will be dealt with later, because, in the actual manufacture of power valves, experience has shown that certain difficulties arise directly consequent on determining arbitrarily certain quantities at too early a stage in the design.

Even so, in particular cases, modifications are often necessary and the design may have to be slightly altered several times before the final form is arrived at. We shall now attempt to discuss in some detail the various factors of design as tabulated above.

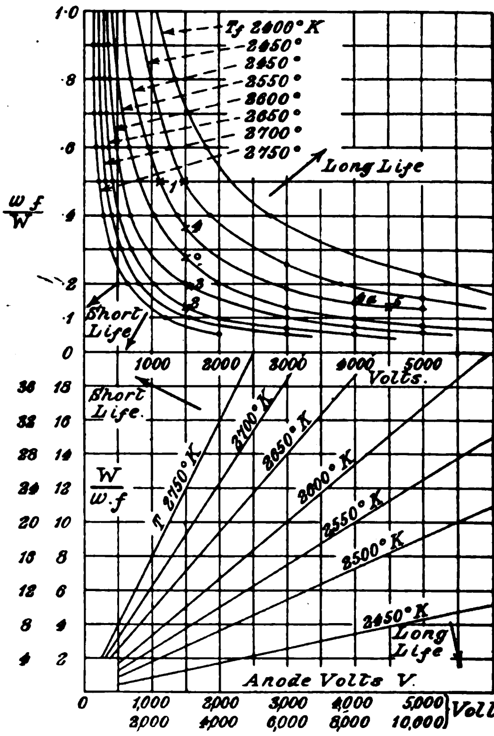


Fig. 2.—Relationship between Anode Voltage, Anode Power, Filament Power and Temperature.

(*a*) The general consideration of the proposed form of power supply to the anode and filament, and the temperature of the latter.

Usually the general form of the anode current grid voltage characteristic taken at

voltage V of the high-tension supply will be as shown in Fig. 1.

When oscillation takes place in the associated circuit the fluctuation of grid voltage will cause the anode current to vary from zero to the saturation value Ce with a mean value of approximately $\frac{1}{2}$ Ce. Thus, the mean power taken from the H.T. supply is $\frac{1}{2}$ CeV, which we may denote by W. Now, to be capable of emitting an electron current of the full value Ce the filament must have sufficiently large an area maintained at a sufficient temperature T_f.

The watts required to maintain such an area at the temperature T_f increase rapidly with the temperature, but the electron current obtainable from that given area increases more rapidly still; hence the ratio filament watts/saturation current, "watts per ampere of electrons" denoted by $\frac{wf}{Ce}$ decreases rapidly with increase of temperature for tungsten surfaces, and we may therefore write

$$\frac{wf}{Ce} = f\,(T_f) = \left(\frac{w^1 f}{0{\cdot}3\,l^1}\right)$$

where $w^1 f$ is the watts required by and l^1 the electron current given by a tungsten cylinder 1 cm. long and 1 cm. in diameter. The factor 0·3 is a correction factor based on practical experience, and will be explained later.

For a given anode supply W a low value of the anode voltage V will mean a high value of Ce, and therefore either a large wf or a high T_f.

The actual relationship between these factors being

$$V = 2\left(\frac{W}{wf}\right)\left(\frac{w^1 f}{0{\cdot}3\,l^1}\right)$$

and is shown diagramatically in Fig. 2.

The desirability of making V as large as is conveniently possible is at once obvious, but, unless extremely long life is desired, it need not in most cases exceed 3,000 volts. In order to take advantage of the longer life given by a low filament temperature, either a high proportion of filament watts must be allowed or else the anode voltage must be high.

In Fig. 2 the numbers marked correspond to certain valves in use under normal operating conditions.

(1) A valve of 100 watts rating gives a long life of several hundreds of hours, but has a somewhat high filament power.

(2), (3) and (4) are 250-watt valves having similar characteristics and designed for the same voltage, but the life of (2) is comparatively short.

(4*a*) is the same type of valve as (4) but the power has been increased by increasing the anode volts, leaving the filament adjustments unaltered.

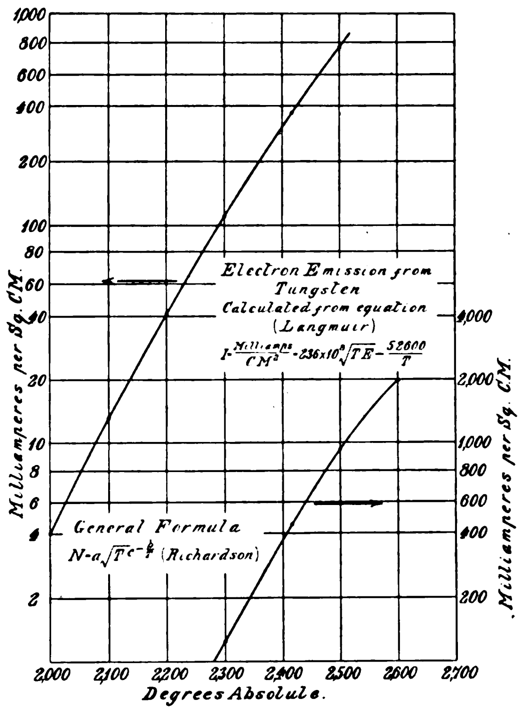


Fig. 3.—Emission from Tungsten plotted against Temperature.

(5) is a high-power valve of 1,500 watts rating.

Note.—The ratings given above are the safe dissipation at the anode of the valve.

Basis of Filament Design.

The numerical data on which the design of tungsten filaments is based are taken from two papers by Irving Langmuir, *Phys. Rev.* (Amer.) N.S. II, page 450, 1913, and *Phys. Rev.* (Amer.), N.S. VII, March, 1916, and the graphical results are those shown in Fig. 3.

The observed electron current differs slightly in similar types of valves and corresponds to a temperature about 150° C. below the calculated value.

Causes which may be contributing to this discrepancy are, in order of their probable importance :—

(1) A reduction of electronic emission caused as described by Langmuir by traces of residual gas.
(2) A difference in the specific resistance of the tungsten wire used and its temperature coefficient.
(3) Insufficient allowance for the cooling of the ends of the filament.
(4) The diversion of a certain proportion of *wf* (about 5 watts per ampere of electrons emitted) to supplying the "latent heat of evaporation" of these electrons.

It is found that the simplest method of correcting for this disagreement is to take

$$Ce = 0{\cdot}3\ I,$$

which is nearly the same as moving the I curves 150° C. to the right relatively to the others. If, in accordance with the second supposed cause corresponding corrections were made of C_f, V_f, etc., they would be smaller but more confusing in use.

It is clear that the correction (2) implies that what is in this article termed the "temperature" of the filament is probably higher than the true temperature. To correct for this would necessitate shifting all the curves to the left.

Measurements available tend to confirm this view, hence the tendency is to underestimate rather than over-estimate the life of the filament.

Dushman, in the *General Electric Review*, XVIII (page 156, March, 1915) states that the life of a filament at a given temperature increases with its diameter, but without a measure of true temperature it is difficult to make fair comparisons.

(*To be continued*).

The Design and Construction of a 50-cycle Transformer for Production of High-tension Voltages.

By L. E. OWEN.

Below are given the constructional details of a transformer suitable for lighting the filaments and providing the anode voltage for a small power transmitter, which has been employed by the writer at his station, 2VS.

FOR the past year the author's station (2VS) has been worked at intervals on a supply of D.C. obtained from rectifying high-voltage A.C. from the lighting company's mains. Quite a number of transformers have been employed, each being more or less successful. For some time past experiments have been carried out on the most economical form of transformer by altering the various constants, such as the amount of iron, flux density, turns per volt, and the like. Various difficulties have come up from time to time, and the overcoming of them has given great satisfaction and interest.

For instance, it was found that the drop in voltage occasioned by reactance in the core-type transformer was great, it being remembered that the load is practically non-inductive; consequently a given design of turns and core sizes gave very different potentials on load of the oscillator than on open circuit. For example, the volts off load of a certain design were found to be 800, while when on load of the oscillator the potential dropped to 500, this figure often allowing for reasonable losses in the rectifying system. The same transformer on an induction load four times as great gave a potential of 750. On transferring

similar windings to a shell-type transformer the available potential on the oscillator load was 740 volts.

It will, therefore, be evident that, owing to the nature of the load, it will be no easy matter to predict the actual output of any one design of transformer.

After some months of experimenting the design hereinafter described was completed, and has given great satisfaction. It is thought that a description of the machine will be of some assistance to amateurs who have experienced similar troubles.

The supply voltage was 220 at 50 cycles, and it was finally decided that the transformer should be of the shell type and that stalloy iron should be used for the core. Accordingly the core was designed to be capable of dealing with a constant load output of 230 actual watts, made up thus: For power (main secondary), 2,500 volts at 60 milliamps.; for oscillator filament (one low-voltage winding), 8 volts at 4 amps.; for rectifier filaments (two low-voltage windings), 8 volts at 3 amps.

After due allowance had been made for losses, of iron, copper and those due to reactance, it was decided that a core suitable for 250 watts would be a convenient size to adopt.

A cross-sectional area of 2·25 sq. ins. was chosen as being a liberal allowance, having a length between cheeks of 5 ins., with a window clearance of 2 ins. The dimensioned sketch (Fig. 1) will show the sizes of the core.

It will be noticed that, as in standard practice, each half of the shell has half the main cross-sectional area of the main limb. The core was constructed of stalloy ·002 in. thick, having a patent insulation on one side of each lamina, the laminæ being of the following size: Main core, $1\frac{1}{2}'' \times 5\frac{3}{4}''$; tops of shell, $\frac{3}{4}'' \times 5\frac{3}{4}''$; sides, $5\frac{1}{4}'' \times \frac{3}{4}''$; butts, $\frac{3}{4}'' \times 2\frac{3}{4}''$.

We will at this point calculate the weight of the iron core, and on measuring up the size we find that we can consider it as a bar of iron of $2\frac{1}{4}$-sq. in. section and $(6\frac{1}{2}+6\frac{1}{2}+4)$ 17 ins. long.

$\therefore$ Volume of iron $= 17 \times 2\frac{1}{4} = 38$ cub. ins. (about).

As the iron is covered on one side by insulation deduct 10 per cent.

$\therefore$ Total volume of iron in cub. ins. $= 38 - 3{\cdot}8 = 34{\cdot}2$

Now, 1 cub. ft. of stalloy (uninsulated) weighs 420 lbs.

$$\therefore \text{ Weight of core } = \frac{34{\cdot}2 \times 420}{1{,}728} = 8\tfrac{1}{4} \text{ lbs. (about).}$$

This calculation being required for losses computation in the iron.

The fundamental equation for all transformers is one in which there are several unknowns, and is as follows:—

$$E = 4{\cdot}44\ T\ \varphi f\ 10^{-6}$$
$$\text{or } \frac{4{\cdot}44\ T\varphi f}{100{,}000{,}000}$$

when E = applied voltage.
4·44 is a constant.
T = number of turns.
φ = flux density per unit area × area.
f = frequency of supply.

Now, we know the cross-sectional area of the core—2·25 sq. ins.—and also E as 220;

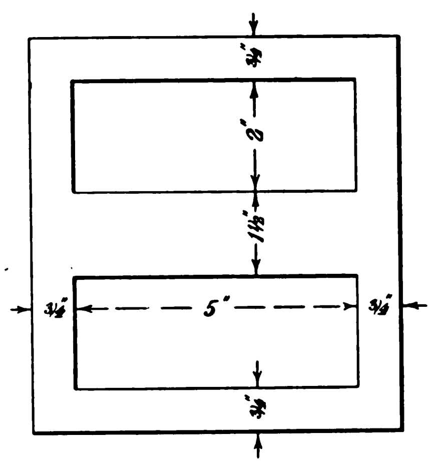


Fig. 1.—Dimensions of the Core.

also the frequency—50 cycles. What we require is the number of turns on the primary. However, we do not at present know the flux density per unit area. We shall, therefore, consider a reasonable figure for working on.

First, let us assume that the number of turns per volt shall be 3. In order to produce ·33 volts per turn of wire the flux must charge at the rate of 33,333,333 lines per second.

Now, the sectional area of the core is 2·25 sq. ins. Therefore, in order to produce this charge each square inch of core section must carry—

$$\frac{\left(\frac{33,333,333}{2}\right)}{2\cdot 2} = 7,500,000 \text{ lines per second.}$$

Now, owing to our frequency being 50 cycles, it follows that the flux density per half.cycle is—

$$\frac{7,500,000}{100} = 75,000.$$

For stalloy iron this is a reasonable figure, and we may now proceed to solve the equation for the number of turns—

$$E = \frac{4\cdot 44\ T\varphi f}{100,000,000}$$

$$220 = \frac{4\cdot 44\ T\ 75 \times 10^3 \times 2\cdot 25 \times 50}{10^8}$$

$$= \frac{4\cdot 44\ T \times 75 \times 2\cdot 25 \times 5}{10^4}$$

$$= 3\cdot 75\ T$$

$$T = 825.$$

Having now arrived at the number of turns for the primary, we must now consider the three secondaries.

(*a*) Main secondary—

Volts required 2,500.

$\therefore$ Turns $= 2,500 \times 3\cdot 75 = 9,375$.

(*b*) Three secondaries to give 8 volts.

$\therefore$ Turns $= 8 \times 3\cdot 75 = 30\cdot 00$.

The figures for the secondary turns do not at present take into account the copper and iron losses, which we shall next consider.

From the curve accompanying the iron it was seen that the total iron losses at 50 cycles for stalloy working at a flux density of 75×10^3 lines per square inch is 2 watts per pound. Now, the weight of our iron core is 8·25 lbs.

$\therefore$ Total iron losses $= 8\cdot 25 \times 2 = 16\cdot 5$ watts.

Now copper losses—

Primary total length of wire = length of average turn × No.

$$= \frac{7\cdot 5'' \times 825}{12} = 517 \text{ ft.}$$

Now, maximum current primary has to carry—

$$= \frac{\text{total rating in watts}}{220}$$

$$= \frac{250}{220} = 1\cdot 137 \text{ amps.}$$

Say 2 amps. for safety.

In order to get low losses we will take 22 S.W.G. double cotton covered. The resistance of this gauge per 1,000 yards is 39·7, say, 40 ohms.

$\therefore$ Resistance of one primary $= \frac{517}{3} \times \cdot 04 = 6\cdot 88$

$\therefore$ C^2R loss $= 6\cdot 88 \times (1\cdot 137)^2$
$= 8\cdot 9$ ohms.

Similarly with low-tension secondaries for filament lighting—

$$\text{Length} = 30 \times 3 \times \text{length of mean turn}$$
$$= \frac{30 \times 3 \times 30 \text{ ft.}}{12}$$
$$= 225 \text{ ft.}$$

Now, gauge of wire to carry 4 amps. safely is, say, 16 gauge. Resistance of 225 ft. of 16 S.W.G. at 7·6 ohms per 1,000 yards

$$= \frac{\cdot 0076 \times 225}{3}$$
$$= \cdot 57 \text{ watts.}$$

$\therefore$ C^2R losses $= \cdot 57 \times$ average current of three secondaries
$= \cdot 57 \times (3\cdot 3)^2$
$= 6\cdot 3$ watts.

Lastly, C^2R losses in secondary for high voltage is found similarly.

Length of secondary $= 9,400 \times$ aver. length of turn
$= 9,400 \times 13\cdot 25''$
$= \frac{9,400 \times 13\cdot 25}{12 \times 3}$ yards
$= 3,466$ yards.

Now, gauge of wire suitable for the secondary will be about 34 S.W.G. single cotton covered, which has a resistance of 368 ohms per 1,000 yards.

$\therefore$ R of secondary $= 3\cdot 466 \times 368$
$= 1,277$

$\therefore$ Losses $= 1,277 \times (\cdot 06)^2$ watts
$= 1,277 \times \cdot 0036$ watts
$= 4\cdot 5$ watts.

Now our total losses are as follows :—

	Watts.
Main secondary	4·5
Three low-tension secondaries ...	6·3
Primary	8·9
Iron	16·5
	36·2

This computation of losses is an exceedingly liberal one, as the lengths of the windings have big positive allowances.

The efficiency of the transformer should next be considered. On full load our transformer is rated to deliver 250 watts, but of this number we find that 36·2 are accounted for by iron and C^2R losses.

$$\therefore \text{Efficiency} = \frac{\text{watts delivered}}{\text{watts supplied}}$$
$$= \frac{213\cdot 8}{250}$$
$$= 85\cdot 5 \text{ per cent.}$$

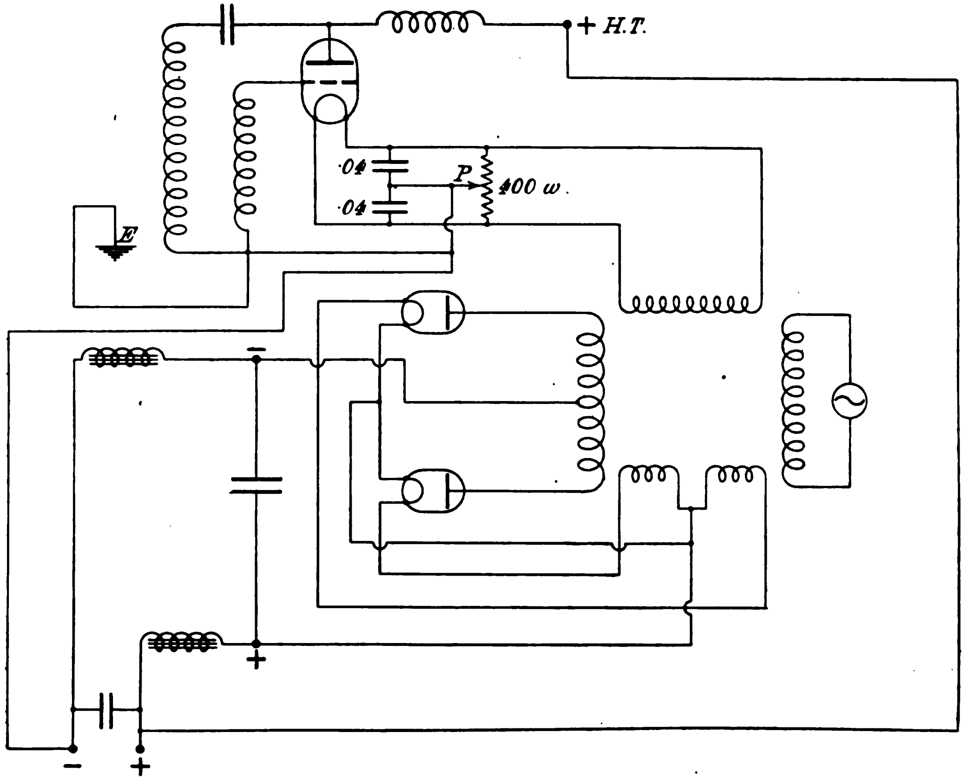


Fig. 2.—Showing the Connections of the Transformer to the Set.

It is interesting to note that the ratio of iron to copper losses is 16·5 : 19·7, or as 1 : 1·19, which ratio is satisfactory for a transformer of this class.

We must next consider the insulation. Probably the most convenient to use and work will be micanite. This substance may be readily cut with shears and made to take the shape of the former by the application of heat. For the primary a piece of this material should be formed round a wooden block, the same as the cross-section centre limb of the transformer, and 2 ins. longer, *i.e.*, $1\frac{1}{2} \times 1\frac{1}{2} \times 7$ ins., and fitted with an end-piece nailed on one end 5 ins. × 5 ins. The other end should have a similar end-piece on it, with a square hole cut in the centre, and provided with some means of clamping it so that it gives a clearance of 5 ins. for the main winding, and also so that it may be advanced for winding the secondary sections.

Next, two end checks should be cut from micanite $\frac{1}{8}$ in. thick, and one firmly secured to the square micanite tube insulation referred to above and held to the face of the wooden end-piece by adhesive tape. The other end should be similarly fixed to the movable wooden end-piece, but not to the tube, in order that the secondary section may be slipped into place. The primary is then wound on in eight layers of 103 turns each. It will be found that there is room for slightly more turns per layer, and packing of worsted soaked in wax must be carefully put into position to make up this deficit. Next a second layer of micanite, $\frac{1}{8}$ in. thick, must be placed over the primary and the low-tension winding placed into position, insulating them the one from the other by 3-32nd-inch micanite and bringing out the ends of each winding to the sides of the bobbin; and, finally, a further tube of $\frac{1}{8}$-in. micanite is placed over the whole of the low-tension windings. If the winding has been carefully carried out this series of windings will present a cross-sectional area of not more than 3·6 ins., leaving a window

space depth of nearly 1 in. on each winding for the secondary.

This will be found plenty for the high-tension winding, which should be wound in eight sections. This is a convenient number, as the R.M.S. volts per section will not be more than 315. The peak value of this should not be greater than 475, so if we insulate for a potential of 800 volts (1-16th-in. micanite) between sections we shall be on the safe side.

The low-tension windings are next removed from the former, and a dummy of wood of the same overall cross-sectional area, *i.e.*, 3 ft. 6 in. by 3 ft. 6 in., and of ½ in. in length, is placed in its stead and the movable check brought up in its place. The former, by the way, should be made of oak or some good hard, well-seasoned wood, as the former and each secondary section has to be boiled in wax; 1,200 turns of wire are put on each section, and are then boiled in wax, care being taken to remove them from the former just before they are cold. When all the sections are finished they are slipped on over the primary and connected up to form one continuous winding all in the same sense, and having a tap brought out from the connecting point between No. 4 and No. 5 sections for the centre earth point of the transformer.

It will be noticed in the accompanying diagram that an extra micanite washer of ⅛ in. thickness is placed between the main check of the winding bobbin and the outside of the first section at each end of the secondary, and its purpose is to prevent creeping leakage which might occur.

The low-tension windings should be given a coat of shellac varnish or bakelite solution on each layer, which should be allowed to dry, final exclusion of all moisture being obtained by passing a current of sufficient magnitude through all the windings in series to obtain a hand-warm rise in temperature. This current should be allowed to pass for about one hour, taking care it is not sufficient to damage the insulation of the windings.

The resulting transformer will be found to give good results, and may be relied on not to overheat on quite long runs. It is not claimed that it is the last word in efficiency, but it is claimed that it will deliver its rated output if properly constructed.

Special attention must be paid during winding as regards insulation, and especially that care be taken to wind the turns as closely as possible, the secondary sections being wound as evenly as possible so as to get the turns in as small a space as they will go.

Lastly, it should be noted that the potential delivered by the secondaries are calculated for R.M.S. values. We, therefore, have peak voltages of considerably higher values in the case of the low-tension winding. We can control this by series resistances to the filaments of the values to be lighted. Now, regarding the secondaries H.T. winding, we must remember that the peak voltage is the value that the rectified D.C. would be were it not for losses in the smoothing chokes and losses due to the impedance of the rectifying value or values, and the author has found in practice that the total drop due to these circumstances does not greatly, if at all, exceed the difference between the R.M.S. value of the secondary potential and the peak value; therefore, the final rectified potential on load should be approximately the same as the rated R.M.S. potential of the voltage delivered by the secondary.

In conclusion, it is thought that a diagram of connections (Fig. 2) of an oscillator supplied by A.C. to the filaments would be of interest, together with the direct supply of A.C. to the rectifier tubes.

The potentiometer slider P is moved until no A.C. is heard in side tone, and such an arrangement is perfectly suitable for use with radio-telephony.

A Few Observations on the Recent American Re-Radiation Tests.

By ERNEST W. BRAENDLE.

We give below details of some interesting experiments which have been carried out by a contributor and should prove of interest to our readers.

IT was the writer's privilege during the recent re-radiation of KDKA to listen simultaneously to both KDKA direct and to KDKA as re-radiated by the British Broadcasting Company. A description of the method employed, together with a few observations, will no doubt be of interest to readers.

Two entirely separate sets were used, one being a two-valve receiver capable of receiving KDKA on 100 metres, and the other a normal broadcast receiver, each, of course, having its own aerial and earthing system. The output of these sets was brought through a switching arrangement which permitted of both ear-pieces of a pair of 'phones being connected to each set in turn, or else one ear-piece to each receiver. Quite early on it was decided to keep to the latter arrangement, as by suitably adjusting the receivers, strength of signals in the 'phones was kept balanced and simultaneous comparisons obtained.

It may be as well, perhaps, to give briefly the main effects noticed, which, although not numerous, were sufficient to suggest possible applications to which re-radiation might be applied, in the hope of obtaining reliable information on at any rate, one or two of the important problems which the present-day engineer has to face.

Static and atmospheric conditions were in every way identical.

Fading, which at the time was occasionally very bad, was exactly similar, except when the B.B.C. varied their receiver.

There was quite an appreciable time lag between direct reception and that re-radiated by the Manchester station of the British Broadcasting Company. This was in the nature of one-hundred-and-fiftieth of a second, and took the form of a slur from one ear-piece to the other, which reversed itself when the ear-pieces were changed over.

It was quite evident that the B.B.C. were using a highly selective receiver, as there was some distortion due to selectivity. Also spark interference, noticeable on the comparatively flatly-tuned 100-metre receiver, was not present in the B.B.C.'s transmission.

The quality of the re-transmission was from 3 per cent. to 5 per cent. worse than direct reception.

Perhaps of these observations the ones referring to static conditions and fading are those having the most importance. It must here be remembered that the signals were received in London by the B.B.C., re-radiated and checked in Manchester. So much has been done in recent years with regard to studying these conditions in different parts of the country and making comparisons in the hope of coming to some definite conclusion regarding them, that the possibility, and, indeed, the advisability, of some simultaneous checking on the lines mentioned is obvious. Let us suppose that the B.B.C. or the Government of this country could be persuaded to re-radiate from each of their stations in turn for a short period, say five minutes every evening, either before or after broadcasting hours, nothing but the existing atmospheric conditions pertaining in their district on whatever wave-length should be considered suitable. This could be simultaneously checked, not only in every part of this country, but also on the Continent both officially and by interested amateurs. By this means a great deal of data, not so greatly affected by the human factor, which has been a great source of error so far, would be forthcoming.

As regards time lag, although interesting, one can see nothing in it other than as a factor which must be taken into consideration whenever a high degree of accuracy is required, such as the possible re-radiation of time signals, etc.

The observation on the comparative quality of the re-transmission need not be taken too seriously as a factor, as a large proportion of the observed distortion was due, as has been previously mentioned, to the use by the B.B.C. of a super-selective receiver.

To the uninitiated these tests have probably been quite interesting as a novelty, but the results, so far as the public are concerned, have not seemed to warrant the very great expense entailed. This has not been the fault of those concerned, but due rather to the perversity of nature. These tests have had, unfortunately, to be advertised some days previously, in order to meet the public demand, with the inevitable result that at the advertised times conditions have been anything but at their best. The writer has not once but several times listened to KDKA when reception has been quite as good as listening to distant B.B.C. stations in this country, and that for periods of an hour or even more. It may be of interest here to add that, having listened almost continuously to transmissions by KDKA for the past few months, a very considerable improvement has been noticeable both in strength and quality since the end of January. So much so indeed that it is now possible to receive this almost regularly on a two-valve (detector and low-frequency) receiver.

At the present time re-radiation of American stations, or any other stations for that matter, has been little more than an interesting experiment, but it surely does not require a very great stretch of imagination to foresee the time when semi-automatic wireless repeater stations, on the lines of the existing long distance telephone systems, will be set up.

Cementing Metal to Glass.

By J. F. CORRIGAN, M.Sc.

Writers on the experimental aspects of wireless construction have often dealt with the possibility of employing glass panels in receiving sets in place of the more usual ebonite. Whilst there are many disadvantages to be encountered in the use of glass panels, such as their extreme brittleness and the great difficulty which is ordinarily experienced in drilling holes into them, the employment of glasswork in radio apparatus is not without several good features. It is not opportune, however, to dilate here upon the relative advantages and disadvantages which attend the use of glass as a material for wireless construction, but the following note on the preparation of a metallic cement which is very efficient for the purpose of joining together glass and metal-work may be of interest to those amateurs whose experimental work lies in this direction.

An alloy of the composition given below should be carefully prepared by fusing in a graphite or metal crucible the constituent metals and stirring them well together. The alloy melts at 212° F.:—Lead, 3 parts; tin, 2 parts; bismuth, 2–3 parts.

Metallic bismuth can be obtained in the form of small cast sticks at any good firm of manufacturing chemists. The metal is not very expensive, its present price being in the neighbourhood of 1s. 6d. an ounce.

The prepared alloy presents a dull greyish appearance. In order to join glass and metal together, the parts should be well cleaned beforehand, and the surfaces roughened by rubbing with a fine file or a piece of coarse sandpaper. The two surfaces which are to be joined together are first warmed to a temperature of about 80° C., and the cement is applied to them in a manner similar to the ordinary operation of soldering. If possible, it is advisable not to use any flux during the operation, but if the use of the latter material is found to be absolutely necessary in order to make the alloy "grip," only a very small amount of pure rosin should be applied.

As will be readily understood, the

successful performance of the cementing process requires a little practice for its achievement. It should be observed that the glass-work must be thoroughly warmed before the alloy is applied, otherwise it may crack owing to the effect of uneven heating. At the same time the metal part of the joint must not be heated to that temperature at which it will become covered with a coating of oxide.

If a cement such as the above is carefully prepared, it will be found to possess many uses for wireless and general electrical instrument construction. Among one of its many uses may be mentioned the joining of the bulbs of electric lamps to their metal holders, and for the radio amateur who is sufficiently enthusiastic and daring to attempt the repairing of his valves the cement is worth making for this purpose alone.

The Heaviside Layer and How it may be Produced.

By O. F. BROWN, M.A.

IN the first number of EXPERIMENTAL WIRELESS the writer described some of the effects which the existence of the Heaviside layer might be expected to have upon the propagation of wireless waves. As explained in that article, the Heaviside layer is the name given to those layers of gas in the upper regions of the earth's atmosphere which are believed to be rendered conductors of electricity by the presence of ions or other electrically-charged particles. In the present article it is proposed to consider shortly certain astrophysical hypotheses which may account for the production of such layers.

In the first place it is hardly possible to suppose that the existence of such charged particles can be accounted for by the ionisation caused by the direct action of the sun's light upon the gases in the upper atmosphere. There is very little evidence that ultraviolet light, unless it is exceedingly intense, has any considerable ionising effect upon a gas, and even if it were possible for ions to be produced by such action they would disappear rapidly by recombination during the dark hours, or just at the time when the effect of the Heaviside layer is assumed to be most marked.

About two years ago, however, Prof. Fleming suggested in a lecture before the Royal Society of Arts that the production of the Heaviside layer might be due to the collection in the upper atmosphere of charged *dust* particles projected from the sun. This theory is based on a modification of a hypothesis advanced by S. Arrhenius, a Swedish professor, to account for certain cosmic phenomena—in particular the repulsion of the tails of comets as they approach the sun. To explain such repulsion the presence of a repulsive force, which under certain circumstances must be more powerful than the pull of gravity, is essential. Ordinary electrostatic attraction fails to account satisfactorily for the facts, and, extraordinary as it may seem at first sight, scientists were led to seek this repulsive force in the pressure exerted by the sun's light on the particles forming the comet's tail, since it can be shown that the pressure due to this cause when acting on particles of a certain size and density can be stronger than the attraction of gravity on the same particles.

That light exerts a pressure upon a body on which it falls can easily be shown from the principles of the conservation of energy. For suppose that a plane wave of light or some other form of radiation is falling upon a body of area q which completely absorbs all wave-lengths. Then the amount of energy absorbed in time t is

$$EqVt,$$

where E is the radiant energy in unit volume of the medium due to the wave, and V is the velocity of light. If now the body on which

the wave falls is displaced a small distance d in the direction from which the light comes, then the energy which falls on the body in time t is reduced by

$$Eqd$$

The amount of heat developed in the body is reduced by the same amount measured in mechanical units. But by the principle of the conservation of energy the loss must be represented by the work gained through the displacement of the body. Since work is measured by force multiplied by distance, the radiation must therefore exert a pressure on the body. If then p represents this pressure, the work gained is represented by

$$pqd$$

$$\text{Hence } pqd = qEd$$

$$\therefore p = E.$$

or the pressure of light or other radiation which is exerted by a train of plane waves falling perpendicularly on a perfectly absorbing body is equal to the amount of energy of the incident waves contained in unit volume of the medium.

In the case of bodies which reflect some of the radiation $p = E\ (1+\epsilon)$ where ϵ is the reflecting power of the body. This theoretical result has been confirmed in a remarkable manner by the careful laboratory experiments of Lebedew, Poynting and others.

It has been calculated that the total pressure on the earth's surface due to the radiation of the sun is about 75,000 tons, while the attraction of gravity is 40 billion times this pressure. The pressure of radiation, however, depends on the area of the surface of the body on which it falls, *i.e.*, in the case of a sphere on the radius squared; while the attraction of gravity depends on the mass of a body, *i.e.*, the density multiplied by the volume, or, in the case of a sphere, on the radius cubed. Both the forces decrease as the square of the distance, but it can easily be seen that as the radius decreases the two forces become more nearly equal. Thus, for a body of the same density as the earth, whose diameter was 1/40 billionth that of the earth, the two forces would balance. The radius of such a body would, however, be less than the wave-length of violet light and scattering and diffraction phenomena would have an important effect, and as a result a particle of that size in the neighbourhood of the sun would be attracted and not repelled. For the same reason the force of repulsion of radiation pressure on the molecules of a gas cannot be as great as the attraction of gravity upon them.

It can be shown, however, that in the neighbourhood of the sun with particles of unit density equilibrium can be established between gravity and radiation pressure on particles whose diameters are ·0015 mm., and similar particles whose diameters are between this value and about 0·3 times the wave-length of violet light will be repelled by radiation pressure rather than attracted by gravity. For particles of the right size and density the repulsive force may be several times the attractive force.

The question then arises as to how such particles of the right size and density can be supplied by the sun. The sun spots observed on the sun's surface are now known to be in reality the craters of vast volcanoes through which clouds of gases are expelled into the sun's outer atmosphere, and it is probable that smaller expulsions of gases are continually taking place. It is also highly probable that these masses of gas are in an ionised state either through the action of the heat of the sun or through the presence of radioactive substances produced under great heat and pressure in the sun's interior.

The gases driven out from the sunspots expand rapidly and in doing so may be expected to cool. Applying now to such gases the well-known results of certain experiments of C. T. R. Wilson, in which he showed that if ions are present in water vapour which expands suddenly, then these ions act as nuclei upon which the molecules of the vapour collect to form drops, we should expect the ions contained in the gases projected from the sunspots to act as nuclei for the collection around themselves of molecules of the gases and metallic vapours which condense, as it were, into dust particles in the cooler outer regions of the sun's atmosphere. In his experiments Wilson observed that condensation took place more readily round the negatively charged ions than round those positively charged, and that condensation was made more rapid by the action of ultra-violet light. The general effect then would be the creation in the outer region of the sun's atmosphere of clouds of small particles charged electrically, which are collections of groups of

molecules of gases and metallic vapours making up the sun's atmosphere. Among these collections we may expect to find particles of all sizes. Some will be drawn back by the action of gravity, some repelled by the action of the pressure of radiation with various velocities, while in the case of others these two forces may be equal and such particles may remain in equilibrium so forming perhaps the phenomenon known as the sun's corona.

On the above hypothesis a stream of electrically-charged particles would be continuously driven out by the sun into space. The particles would have various velocities varying between perhaps 300 kilometres and 2,000 kilometres per second according to their size and density. Certain of these particles would be caught in the atmosphere of the earth, where they would come under the effect of the earth's magnetic field which would tend to separate out the positive and negative particles; for in accordance with other well-known laboratory experiments such charged particles will arrange themselves in helixes round the lines of the earth's magnetic force. The greater the velocity of the particles the farther they will penetrate in the earth's atmosphere. Round the magnetic poles the particles will be more closely collected and the production of auroras with their well-known streamers and rays may be explained in this way.

Professor Fleming, however, points out that there is another cause operating to sort out the particles and bring the particles to rest as they approach the earth. This is the viscosity of the atmosphere. By viscosity is meant the frictional resistance which the atmosphere exerts on bodies moving through it. Stokes proved many years ago that a small sphere of diameter d and density σ falling through a gas of density ϕ and viscosity μ under the action of gravity attains a final velocity

$$v = \frac{1}{18}\frac{d^2 g}{\mu}(\sigma - \phi).$$

where g is the acceleration due to gravity. At the earth's surface this relation explains the slow rate of fall of the water drops constituting clouds.

It has long been known that the viscosity of a gas was independent of the pressure over a wide range of pressures. Thus the viscosities of nitrogen and oxygen are of the same order of magnitude and are constant for pressures between about one atmosphere and one-thousandth of an atmosphere, but below this pressure their values fall rapidly to zero. Hence the effect of the viscosity of the atmosphere in checking the approach of the dust particles to the earth will only begin to be effective at a height of about 100 kilometres and the particles will be sorted out and practically brought to rest at a height of some 80 kilometres. At this height the sorting process may result in the formation of a conducting layer such as we believe the Heaviside layer to be.

These theories are chiefly supported by the explanations they afford of many cosmic and terrestrial phenomena, as in the correlations between sunspot activity and auroras and magnetic storms.

It is interesting to note on this hypothesis of the origin of the Heaviside layer the dust particles making up the layer would probably be of the right size to affect those shorter waves of lengths between 100 and 300 metres which are believed to be reflected by the Heaviside layer in long-distance night transmissions of short waves. Also observations made on the variations of intensity and the direction of arrival of atmospherics appear to point very clearly to a solar control of these phenomena either direct or indirect. Watson Watt in his paper read before the Royal Society on "Observations of Atmospheric Disturbances," 1920-1921, points out that the mean direction of arrival of atmospherics at Aldershot was not widely different from the direction of the magnetic meridian, and states: "The periodic variation of the direction of arrival of atmospherics although vastly greater in amplitude, is in the same direction as that of the magnetic declination and the fact must not be lost sight of in considering the possible common relation of both phenomena to electrical phenomena at very high levels in the atmosphere." If atmospherics were due partly to electric fields radiated by electric discharges between clouds of charged particles forming the Heaviside layer and if, on the hypothesis suggested above, such particles were following the earth's lines of magnetic force, then such a correlation between magnetic phenomena and atmospheric disturbances as Watson Watt suggests might be expected.

On the Influence of Input Connections upon the Operation of Triodes.

By WILLIAM D. OWEN, A.M.I.E.E.

Many experimenters fail to realise the importance of the position of the connection to the filament circuit, and the subject is dealt with below.

THE ease with which amateur constructors can get results with their maiden efforts, despite the number of variables involved, is undoubtedly one of the explanations of the strange spell that wireless casts over its adherents. Encouraged by the fact that the first loosely-conceived and hastily-built receiver actually emits music or speech comparable in quality with that from expensive sets by experienced makers, the novice gives himself up whole-heartedly to the lure of this new cult and immediately starts upon something more ambitious.

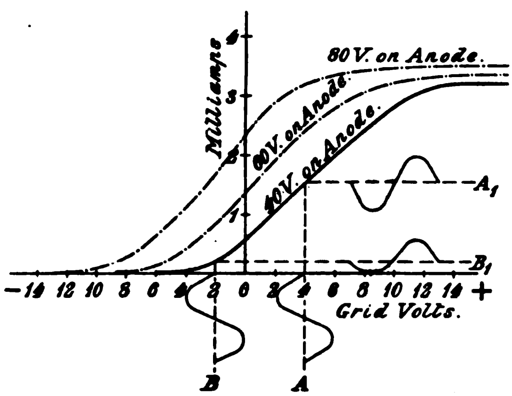


Fig. 1.—Characteristic of B.T.H. R4V. Valve.

In cases where funds permit, the next step is, all too frequently, to pile on valves and to amplify signals up to loud-speaker value, long before the idiosyncrasies of the valve are mastered or the variables in any way understood.

To appreciate the extraordinary possibilities of the valve one has only to be reminded of the fact that American broadcast stations have been heard in this country with a single valve. Results such as this can be achieved only when the several variables are adjusted to certain critical values which, incidentally, differ to some extent with each individual valve. It is seldom, if ever, that two valves of the same nominal type behave quite the same in similar circumstances, hence it is that characteristic curves supplied by makers should not be regarded as strictly true for all such valves.

It is not generally realised that in operating a thermionic valve there are three factors that can be varied apart from variations in the associated circuits, as to which there is no limit. These three factors are filament temperature, plate potential and grid potential.

The designers of commercial apparatus have, of necessity, to keep down the number of adjustable factors in order to simplify the operation of their instruments. It is customary, therefore, to fix the potential of the plate and grid, and to provide a simple rheostatic control for the filament heating current. This explains why amateurs are sometimes surprised and flattered to find that they can get, with two valves, results similar to those obtainable with four or five valves on a commercial set. It is due to the deliberate sacrifice of sensitiveness for simplicity and reliability because of the relatively greater importance of these characteristics in apparatus intended for general use.

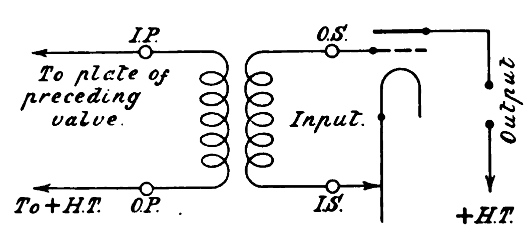


Fig. 2.—The Input and Output Connections.

Experimenters labouring under no such obligation may multiply the number of controls until nobody but themselves can

operate the set. It is then possible to "ring the changes" until the right combination is arrived at, either by accident or by application of first principles. What is generally lost sight of, however, is the fact that the combination suitable for one valve is probably quite unsuitable for another. Yet we are frequently treated to expressions of opinion—apparently from experienced observers—which opinions, when analysed, prove to be based on a comparatively superficial observation of the behaviour of different valves *in identical conditions* regardless of

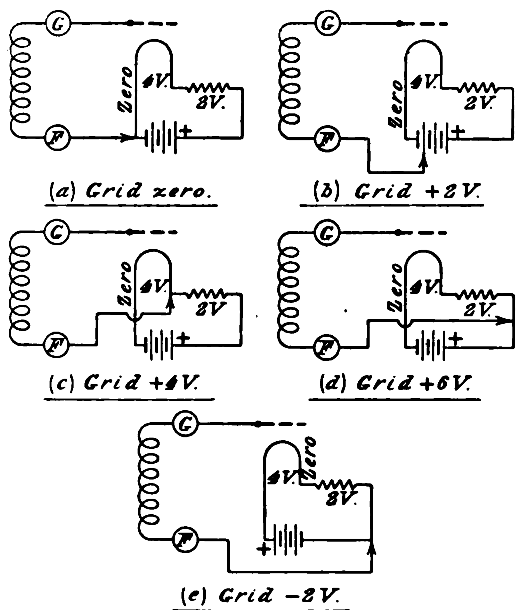


Fig. 3.—The Series of Various Points of Connection.

the fact that these conditions may be favourable to one type and unfavourable to another. An observer whose valve panel is rigidly wired and permits of no modification of grid and plate potential, is not in a position to say that such and such a valve is the best detector or amplifier, as the case may be. All he can say is that it suits his circuital arrangements better than the others he has tried.

The operating characteristic of any triode valve is the relation between the current in the plate circuit and the potential of the grid *relative to the negative end of the filament*. In other words, the "output" current depends upon the magnitude of the grid-potential variations around a certain fixed point which may be called the operating point. If the relation between grid-potential and plate-current were lineal the precise position of this point would be immaterial

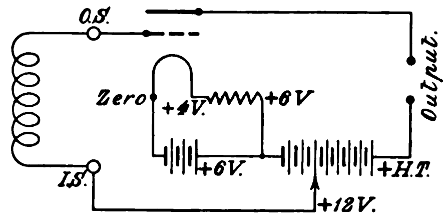


Fig. 4.—Connection to Produce a Large Positive Potential.

(within certain limits). Unfortunately the characteristic curve that graphically depicts this relation is not linear throughout its whole length. It is only approximately straight throughout a portion of its length. The consequence of this is that, unless the operating point falls on or near the straight portion of the curve, distortion is bound to occur.

This is clearly seen by referring to Fig. 1, which shows the characteristic curve of a B.T.H. R4V valve. The normal potential of the grid is the same as that portion of the filament circuit to which the secondary side of the input transformer is connected. If the connections are such as to give to the grid a normal potential 4 volts positive to the negative end of the filament, the operating point is at A, and a grid-potential

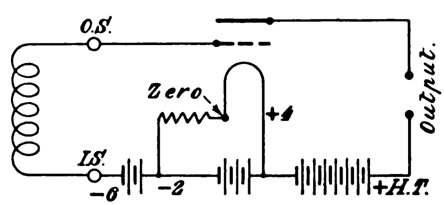


Fig. 5.—Connection to Produce a Large Negative Potential.

variation of $\pm$ 2 volts gives rise to a plate current variation of exactly the same form, as shown at A_1. But if the operating point be at B a similar grid-potential variation (drawn sinusoidal for simplicity) gives rise to the distorted plate-current variation illustrated at B_1. Obviously, therefore, the operating point is of considerable importance and the factors governing it should be carefully considered.

It is not generally appreciated that the input lead from OS, Fig. 2, has five alternative connections and that the normal grid-potential varies from +6 to −2 volts, according to which of these is chosen. The whole series of connections is illustrated in Fig. 3 which is almost self-explanatory. It should be noted, however, that in condition *e* the polarity of the filament battery is reversed, and that condition *b*—which is not so well known as it deserves to be—involves the use of one of the intermediate connections on the accumulator.

Positive potentials beyond the limits specified above may be obtained by connecting to the low voltage end of the plate battery at a suitable distance from the negative terminal Fig. 4. If, however, greater *negative* potentials are required it will be necessary to introduce grid cells connected as shown in Fig. 5.

Danish 7QF.

By THE OPERATOR.

The Danish station 7QF is well known to many transmitters, and we give below some details which have been prepared by the operator.

THE Copenhagen experimental station 7QF is one of the newer arrivals in the fascinating pastime of brass-pounding, as the power has only lately been increased sufficiently to reach outside Denmark. The first A.C.C.W. transmitter was made in June, 1923, a small Philips' power valve being used with the 220-volt 50-cycle A.C. mains as H.T. supply. With this transmitter 7ZM, 20 miles away, was often worked on 330 metres, the aerial current being ·1 amp. with a water-pipe earth. The first improvement effected was the raising of the twin-wire T aerial from an average height of 20 ft. to a flat top height of 35 ft., an aerial series condenser being put in at the same time. This brought the wave-length down to 220 metres and the radiation up to ·15 amp. Several attempts to reach England at this time were made, but without success. In the beginning of December a twin-wire counterpoise was erected, which increased my radiation to ·2 on 195 metres and at once resulted in my being reported by Mr. Geo. Rogers, of Ashford, Middlesex. I next tried rectification of my H.T. A "Ferrix" transformer having two secondaries giving 4 volts each and one secondary giving 200 volts was purchased, the 200 volts being put in series with the mains to give 420 volts A.C. A 20-watt Philips' power valve was then bought, as was also a German 50-watt neon rectifier tube, the latter in conjunction with two paper-insulated 2-mfd. condensers and a Ford coil being used for rectifying the 420 volts. With this I really did get C.W., though only on low power (·1 radiation). Then, at long last, I worked with a foreign station (G5US) on December 30 at 1550 G.M.T. (before sundown in England, Hi !). I have often since wondered how I did it, since my radiation was only ·2. After this I called CQ for many weary hours without avail, until I one day thought of trying to go down to 125 metres. I moved the aerial clip from turn No. 18 to turn No. 3 on the A.T.I, and removed 32 of the 40 turns on my grid coil (I have always used the standard direct-coupled reaction set with tuned grid coil). My radiation was still ·2, but my wave was now 120 metres, and the very next morning, early, I worked 2KF. From then till the beginning of March I worked about a dozen stations of various nationalities. Then my bottle went west. I put in a hard receiving valve instead and got exactly the same radiation ! (True, this with 5 volts instead of 3·8 on the filament.) With this valve I worked until it burst, and then closed down for a thorough overhauling of the station. Towards the

end of April I started work again, but could not reach England any more. Instead, I had a daylight test with Sald (Lund, Sweden, 30 miles from here). He was using four R valves in parallel with 300 volts on the plates, his radiation being ·3 on 170 metres, using the electric bell-wires as a counterpoise system (Hi !). He also tried 'phone, which I received O.K. on one valve, every word being readable. Transmission has been permitted in Sweden for some time, but they are only just beginning to allot call signs, so by the time this appears in print SALD will probably be SALD no longer*. The call signs being allotted are horrid—thus there is one in Stockholm called SMZZ. I have now closed down my transmitter, at any rate for the summer, as I believe the authorities are beginning to wake up and start searching for us ; I consider it the best policy to stop before being caught. However, my interest in "DX" is undiminished, and I still listen on short waves and send reports to the stations heard—I have 400 reporting cards in stock! My present receiver is an ordinary one-valve set with loose-coupled tuner ; the valve is of Danish manufacture and contains a slight amount of residual neon gas. It uses 3·5 volts ·4 amps. filament current, and about 30 volts H.T. (critical). This valve is very sensitive, I have heard 2IJ several times when his radiation was only ·1. WGY's carrier on 107 metres comes in R8, but speech is so distorted as to be quite illegible. The B.B.C. stations come through O.K., though I seldom listen for them because of trams, ships and arc-hash (OXE, 8 miles away, 40 kw. input). Most of the listening is done on 600 metres ; on this wave SUH, FFA, GMH, etc., and hosts of ships can be heard any evening. I wonder why so few people listen on 600 metres ; surely it is the most fascinating wave of all. On 200 metres and under I have heard 225 stations since April last year ; on 125 metres, 15 Yanks.

In conclusion, let me state that I am always delighted to undertake special distance tests with low-power stations, and anybody wishing to test has only to drop me a line *via* this paper.

*The call is now SMZV, and the address is : Fil. Dr. G. Alb. Nilsson, Skolgatan 5, Lund, Sweden. He would be pleased to hear from English amateurs desiring to test with him. He generally works on Saturday evenings ; pure C.W. on 200 metres.

The Mechanics of Components.

By GEORGE GENTRY.

Home-made experimental equipment frequently suffers from faulty mechanical details. In the following notes an expert deals with the principles of good design and sound constructional methods as applied to wireless components.

No. 2.—Variable Condenser Construction.

IN the absence of any useful standard components of variable condensers, it is proposed to centre these notes around a design, which the writer offers as embodying about the best arrangement of simple standard fittings to make up a condenser, which is designed to meet the following mechanical and electrical requirements :—

Avoidance of dielectric losses in the end plates, and yet to use a metal foundation. Good electrical connection between consecutive plates and consecutive vanes. Rigid construction of such a nature that the relationship between the vanes and plates is not likely to alter with time. Minimum capacity to be as small as possible as compared with maximum capacity. And the condenser moving parts to have a simple adjustment that will allow of movement to be made stiff enough to retain its setting under ordinary conditions of usage ; although it is not suggested that the design is suitable, in this respect, to be used with its spindle in a horizontal position. The whole of the metal parts to be brass, but if a condenser of this construction were

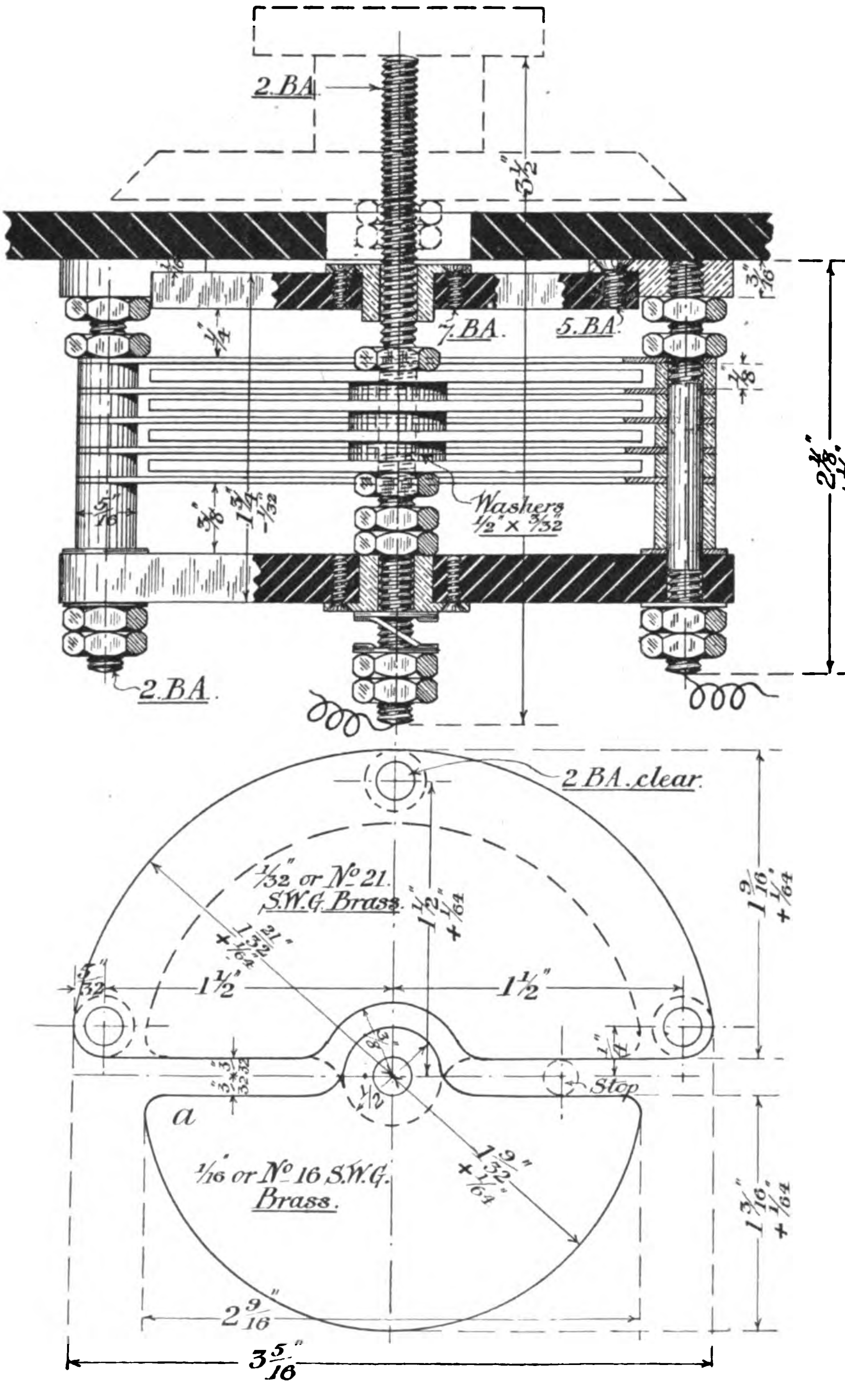


Fig. 1.—Sectional Elevation of Condenser and Plan of Plates.

made in quantities it would be quite permissible to have the foundation half-circular ring made in a die-cast metal, which, however should be as hard a material as could be made by that process, or, at any rate, a somewhat more stable material than the soft metal of which die-castings are usually made.

It is proposed to refer to the stationary plates as the stator plates and the moving plates as the vanes. Fig. 1 shows a front sectional elevation of the condenser as made up of four vanes and five stator plates, and as mounted upon a $\frac{1}{4}''$ ebonite panel. At the moment the writer is not prepared to give this size any particular maximum capacity, but the drawings have been produced and dimensioned in such manner that it would be a simple matter to modify them to agree with any reasonable number of plates and vanes in excess of those drawn. The same figure also shows on plan the relative positioning of the stator plates and vanes at maximum and minimum position, and their respective dimensions. Fig. 2 shows at the top an underside plan of the top plate and foundation ring, and Fig. 3 a topside plan of the bottom plate. All the drawings are to scale and to the scale given on Fig. 2. In Fig. 3, just above the bottom plate, is shown a modified form of vane (at *a*) to which reference will be made.

In order that the best results can be maintained in the matter of conductivity between the plates and vanes and their distance pieces both are to be of brass sheet in preference to any aluminium alloy. The latter on account of its chemical instability is liable to form films of oxide, which must modify conductivity, especially in the case of a large number of plates and vanes. The stator plates are to be of hard brass sheet, especially flat and free from bruises or dents, 1-32nd" thick, or its equivalent standard wire gauge No. 21. The vanes, on the other hand, are to be double this thickness, or No. 16 S.W.G., as being then less liable to deformation by accident. The spacing of the plates being $\frac{1}{8}''$ gives an air space of 1-32nd" each side of vane, which is a dimension rather under that of the generality of condensers and therefore on the side of extra capacity.

The bottom view of Fig. 1 shows the key dimension of the condenser arrangement, *viz.*, the straddle centre to centre of the framing bars 3", or $1\frac{1}{2}''$ on each side of the centre line through the centre of rotation. The holes in the stator plate corresponding to these dimensions are to clear No. 2 B.A. and should be drilled by means of a 3-16th" drill and opened out if necessary by a broach. The plate as arranged to be spaced by a 5-16th" diameter brass distance washer is therefore 3 5-16th" across out to out, and as a whole conforms to many plates of standard size sold. In order to reduce edge capacity to a minimum the vanes and plates face edge-on in the minimum position 3-16th" apart, and this therefore brings the centre of rotation 3-32nd" in front of the front line of plate or vane. That the clearance and capacity space be kept constant between the edges of the vanes and the distance washers of the stator plates, the edges of the plates must be struck in curvature from the centre of rotation. This gives rise to the method of referring to these radial distances both in the drawing of the stator plate, vane, and in the end plates, and also where reference is made to the depth front to back of these various fittings. It will be noticed that for convenience a radial distance or depth is given plus 1-64th" in every case. Looking on the stator plate drawing it will be noticed that the distance $1\frac{1}{2}''$ of the frame hole from the centre line is not on the diameter of the rotary circle, but on a line $\frac{1}{4}''$ higher than this diameter. Therefore if we wish to refer to the radial distance of this hole from the centre of rotation it is equal to $\sqrt{\frac{1}{4}^2 + 1\frac{1}{2}^2}$ (*i.e.*, the square on the line subtending the right angle, in a triangle, is equal to the sum of the squares on the sides containing it). This distance comes out just a shade over 1-64th" over $1\frac{1}{2}''$, and in the view mentioned it will be noticed that the radius of the back of the plate must then be $1\frac{1}{2}'' + 5\text{-}32\text{nd}'' = 1\ 21\text{-}32\text{nd}''$, and this has to have added the 1-64th". To actually set out this plate, however, the best thing to do is to draw the vertical centre line and cross it with a horizontal centre line corresponding to the centres of the holes. Upon the latter measure a distance of $1\frac{1}{2}''$ each side of the former and make centre dots accurately at these two points. Scribe circles from these centres each 5-16th" diameter. Below the horizontal centre line draw another line 5-32nd" below it, and

parallel, to form the straight front edge of the plate, and below this again another parallel horizontal line ½" below the first one. The last drawn line is the cross centre of rotation, and where it crosses the vertical centre line a dot should be punched exactly at the intersection. From this centre the centre of either of the edge holes will be found to be very closely 1½" plus 1-64th", and that, if the dividers be set to 1 23-64th" a little full together to drill the stay holes through all at once, the holes being carefully drilled in their correct positions in the template. The template should also be made with the centre pivot hole so that it could be used to drill the top and bottom frame plates and thus ensure that their holes are in correct position relatively to the centre pivot hole. It should be remembered that in this connection in dealing with the top

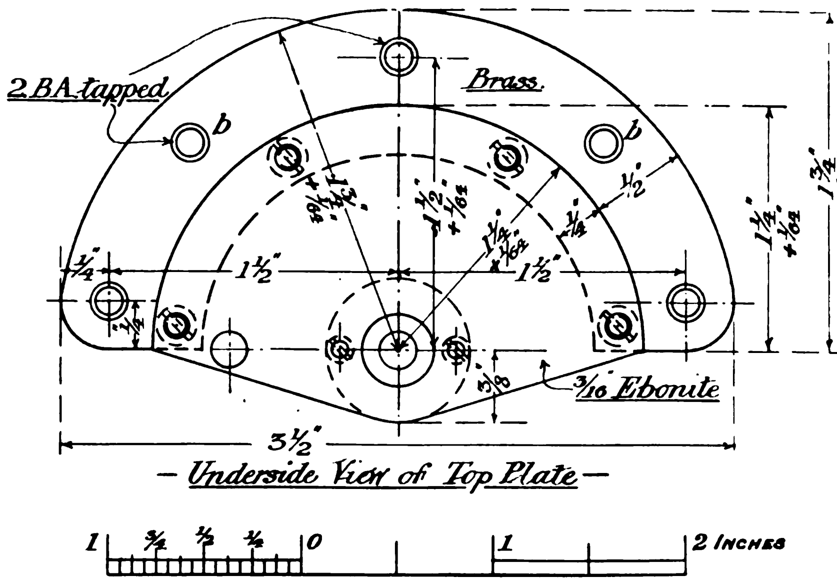


Fig. 2.—Underside Plan of Top Plate.

it will scribe the back curve of the plate tangent to the two 5-16th" circles.

The setting out of the vanes follows that of the stator plates very closely, but it is a more simple operation, as no holes have to be drilled beyond the centre spindle hole. If any number of vanes are required it would be good practice to mount them, having roughed them out and drilled the centre holes, two one way and two the other, close together, and bolt up tightly on a true-running mandrel, and turn the outsides to a diameter of 2 9-16th" plus 1-32nd"; but it would be necessary to run a line of solder along the edges of the boss portion to keep any one vane from moving. If any number of stator plates are required it would also be good practice to make a template of, say, ⅛" brass plate, and use this clamped to the other plates packed semi-circular ring of the top plate the holes would only just be started with a full-size drill (3-16th"), and followed through with a No. 26 drill which is the tapping size for No. 2 B.A.

The top plate, as seen in Fig. 2, which is reversed to show the underside, consists of a metal semi-circle ¾" wide, divided to two thicknesses, *viz.*, outside ½"×3-16th" thick and inside ¼"×1-16th" thick. The inner flange forms a semi-circular rebate to take a 3-16th" thick ebonite plate, and is, of course, ⅛" deep. The ebonite plate which is rounded concentrically to the rotary centre fits snugly in the rebate, and is attached thereto by four No. 5 B.A. countersunk headed brass set-screws screwed downward through a countersunk clearance hole in the brass and into tapped holes in the ebonite. The ebonite is lined at the centre

of rotation with a flanged brass bush, flanged upward, of a standard size sold by all dealers, and holed for No. 2 B.A. clear. This top bearing is only a steady bearing, but as it confines the spindle to the upright it must be of brass to resist wear. The bottom frame plate, Fig. 3, is for cheapness and ease of production all in ¼" ebonite with a similar brass bush. The bush in this case takes the spindle weight and sets it to height by means of a pair of lock nuts on the upper side. The underside of the spindle also carries locknuts, between which and the flange is placed, sandwiched between brass washers, a copper spring washer. The compression given to this spring by the lower nuts determines the required tension on the lower journal of the spindle to retain the vanes at any setting.

The spindle and three frame stays may be screwed throughout to No. 2 B.A., but would preferably be made of 3-16th" round brass, left plain where not required to be screwed, which is within the region of the stator plates and vanes. The bearings must of necessity have screwed journals in them. The frame stays are screwed down ⅝" length from the top, and ½" length up from bottom. The spindle is screwed down 1¾" length from the top, and up 1⅜" length from bottom. The total lengths given refér to a four-vane condenser, and for every extra vane added add 5-32nd" to the lengths given. The bottom plate may be a replica of the top instead of all ebonite, but it should have 3-16th" clear holes through the brass edging and be put on the other way up, in which case no washer

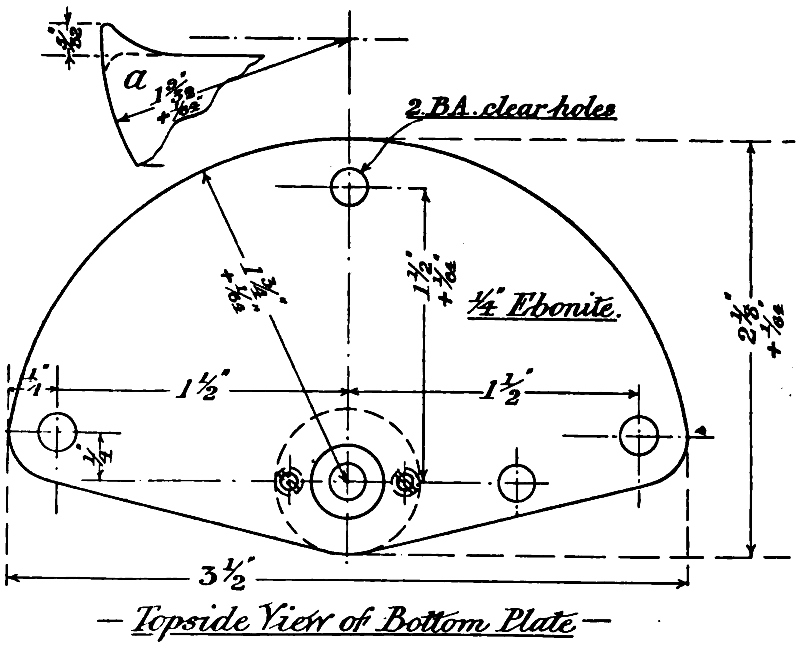


Fig. 3.—Topside Plan of Bottom Plate.

would be required under the bottom spacing tubes, and these tubes instead of being ⅜" long about, would have to be ½" long.

To assemble the condenser, having tapped the three holes in the brass edging of the top plate dead upright, screw in the three stays tightly and flush with the top, checking them by means of the lock-nut, two of which will be put on each. The second lock-nut on each is then arranged to space the top stator plate ¼" from the top ebonite plate, and parallel with it. Held upside down all the stator plates and their ⅛" thick distance washers are put on, finishing with the final long distance tube and washer. The vanes are now put on the spindle and locked as closely to position as possible by their top and bottom nuts, and two extra locknuts are put on bottom of spindle. With the

vanes in the out position the spindle is put up through the top bearing, and the bottom plate put on and secured. After this the positioning of the vanes is effected either by shifting the locknuts immediately above the bottom bearing, or, if necessary, the nuts top and bottom of the vanes.

The locknuts, shown dotted on the spindle beneath the dial, can be put on after, and are suggested as being perhaps a check on some unwary person screwing on the knob and dial too far and thus drawing up the spindle and perhaps deforming the vanes. If the condenser be used self-contained these nuts would not be required, and the dial would be screwed down to read against an index on the brass ring.

The leads, as shown, may be sweated respectively to the end of a fixed stay, and to the end of the spindle, or to the face of the flange of lower bearing. In the spindle connection, however, the best practice would be to sweat a piece of copper flex to the end as shown, and carry it to a screw terminal on the bottom ebonite plate, which terminal should stand as close to the bush and as far from the fixed stays as possible.

The attachment is shown as to a ¼" ebonite panel, and this is effected by screwing to the tapped holes *bb* in Fig. 2 by a pair of No. 2 B.A. countersunk-headed set-screws, passing through the panel and holding up the condenser by the ring.

It remains to point out that with the vanes in the off position, as in Fig. 1, there will be several degrees of movement comparatively inactive as to change of capacity. This may be obviated by making the vanes horned at *a* on the entering side. If the vanes be shaped, as shown in the small detail of Fig. 3, the edge capacity will not be materially increased, whereas these horns entering the stator space will tend to affect the building up of capacity somewhat sooner than otherwise. These horns will, of course, be put only on the one side.

The stop consists of a 3-16th" bar of round red fibre put through holes in the ebonite of top and bottom plates which are shown holed for the purpose on the horizontal centre of rotation and about ⅞" centres from this centre. It may be less, however, but cannot be greater. The bar passes down through the vane and plate gap, and should be flattened slightly over the fronts of the stator plates so as not to touch their edges. Fibre is not a good insulator, and therefore should not connect conductively any two contacts, but it is stronger as a stop than ebonite, and, if dry, must have a lower specific inductive capacity. The bar will act as a stop in both directions, but care must be taken to ensure that it cannot readily be pressed back against the edges of the fixed plates by the vanes when in the off position.

If this condenser be made with a view to rearrangement to add to or deduct from its total capacity by adding or deducting from the plates and vanes, it would be better to mount the plates and vanes loose for the most part or not sweated. In any case, the three points on the stator plates should be tinned, as also each side of every spacing washer, both for the plates and vanes, and also both sides of the centre boss of vanes. All these tinned surfaces may be wiped with an oil rag when hot to wipe off superfluous tinning. Then, if the condenser is to remain intact, build it up with all the tinned surfaces fluxed, and then, when together, by the aid of gentle heating by the blowpipe, carefully applied, all plates and vanes can be sweated to their distance pieces and thus ensure good contact. If left unsweated, however, no flux should be applied, and just before assembling the tinned surfaces should be well cleaned to ensure their making at any rate a clean contact.

To get good results the very best sheet ebonite must be employed in condenser construction, and certainly no moulded material claiming to be ebonite.

"Hands Across the Sea."

By Major Wm. COATES BORRETT

(*Manager, Maritime Division, A.R.R.L.*).

Much has been published on the subject of transatlantic amateur telegraphy from the point of view of the English experimenter. Below we give a brief resume of what has been done in Canada.

THE A.R.R.L. transatlantic tests of 1923-24 will long be remembered by the amateur radio operators of the Canadian Maritime Provinces as the beginning of the real international work for amateur radio. As Canadians it was of especial interest to us to link up with our Mother Country, and the success which has met our efforts has been beyond our fondest hopes.

The Maritime Division, A.R.R.L., being Canada's most eastern division, felt it their special duty to make every effort to connect. Having only about twenty amateur stations in the Division that had worked any distance worth while, it meant that we had to put on all effort possible to compete with our American cousins all along the East Coast of the U.S.A. Of our twenty stations, not more than five or six had ever worked over five hundred miles, and only two had ever been reported from Europe.

We found that in reception the Europeans who came in with regularity were all on short waves, so taking a lesson from this, we went down from the usual 200 metres to around 125. The first station to work England from this part of the globe was C1BQ of Halifax, who linked up with G2OD. The news spread fast, and before long C1DQ had hooked G2SZ. Next C9BL connected with G2OD, then C1DD connected with G2NM, and then C1AR worked G2SH, and the latest two Canadian 1's to get two-way working have been C1DT and C1DJ, both with G2OD. In addition to these, C1BV has been reported in England. All of the above Canadians have connected with inputs of less than 100 watts. The first five have worked Europe so often, especially 1BQ, that it is a rare occasion when at least one or two of them cannot be heard sending messages and exchanging remarks with their brother hams of England.

The Maritime Division, A.R.R.L., feel proud of their work, but it is due to the splendid co-operation which we have received from the English end that has made it possible, and the writer feels it would interest English hams to know how we get their signals. The greatest credit for this continuous nightly communication, in my humble opinion, goes to G2OD and G2NM. These two English stations have been logged and worked, I am sure, on more occasions than any others of Europe. There has scarcely been a night for the last five months but what these two stations have been pounding in here. Other stations have been logged on many occasions, but never with such regularity as these two, who have done more to cement the feeling of Empire unity by radio than any other English stations. They are by far the best known among the rank and file of the amateur gang out here. G2OD has as good a signal as any we hear from Europe, and has been worked more than any other. G2NM is equal, perhaps, in strength, but has not been quite so steady as 2OD in breaking through. 2SH follows them very closely, and has worked most of the Maritime gang. Other English stations logged or worked here are 2KF, 2SZ, 5BV, 5KO, 5NN, 5FS, 6XX, 2WJ, 5OT, and 6RY. The last-named station has only been coming through for the last week, and is evidently a new one. However, he is on a par with the best of them, and, no doubt, will be known as well as 2OD and 2NM and 2SH before long. It might interest our English brother hams to know that the following stations of Europe have been logged in Halifax during the past winter season:

British: (2KF), (2NM), (2OD), (2SH), (2SZ), (5BV), (5KO), 5NN, (5FS), 6XX, (6RY).

FRENCH: (8AB), (8ARA), (8BF), (8BM), (8CT), 8JL, FL.

DUTCH: PA9, (PAODV), NAB2, (PCII), PCTT, PAR14.

ITALIAN: ACD.

Note.—Those in brackets worked.

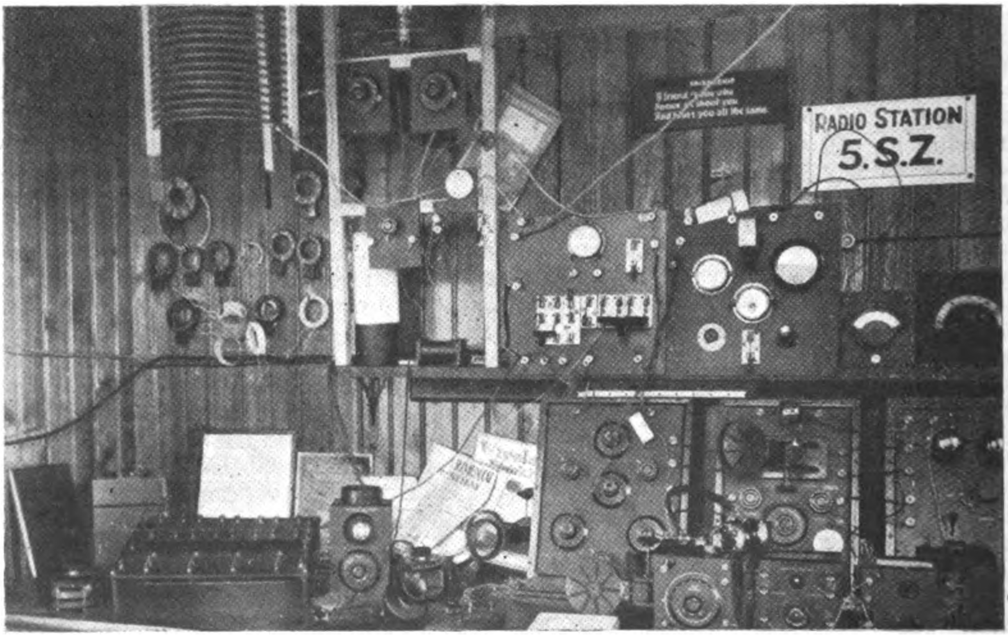
It might also interest our English brother hams to know that the seven Maritime stations that have been successful in two-way work with England have all been able to reach the goal of their ambitions with *inputs* of less than 100 watts. In fact, 1BQ on one occasion worked 2OD with an input of 20 watts, which shows the English amateurs are on the job at reception. One British station, G5US, although he has not worked us, has logged every local station that has worked England. We would particularly be glad to hear of any British stations, and are ready at all times to make tests of any kind.

All Maritime stations to have had two-way work with England to date are located in Halifax or Dartmouth, which is across the other side of Halifax Harbour from the city. It is, therefore, an easy matter to notify them of any tests which the English stations may wish to make.

Let us continue and make "The Royal Order of Transatlantic Brass Pounders" grow.

In conclusion, I trust that all amateur readers of your paper will endeavour to communicate with any Maritime Provinces hams that they hear in future, as in the past.

Radio Station 5SZ.



A general view of 5SZ, which uses two Mullard 0/10A valves in parallel fed from an M.L. converter.

Constructional Notes on Loud-speaking Telephones.

By E. SIMEON.

We give below the results of some experimental work which has recently been conducted on loud speakers.

THE following notes deal with various points in connection with two types of loud speaker: that using an iron diaphragm similar to an ordinary telephone, and the type often called the "electro-dynamic," and perhaps better described as a "moving coil" instrument.

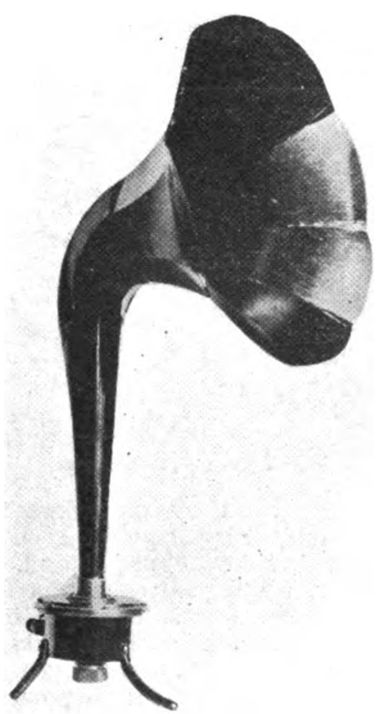


Fig. 1—A loud speaker with a built-up zinc horn.

There are, of course, several other types, such as that using an iron reed; but even on the commercial instrument the results obtained, while exceedingly loud, are somewhat weak as regards quality; and an amateur's attempt is scarcely likely to be an improvement on it.

Effect of Horn.

It is necessary to use a horn if any degree of efficiency is to be obtained. In that type of loud speaker using a large diaphragm and no horn probably only the few square inches in the centre move at all, except at very low frequencies. At all events, much the same results are given with a 2½-in. diaphragm, supported so as to have the same natural frequency, as a 12-in. one. In either case the efficiency is low, nor is the quality appreciably better than can be obtained from a properly-made loud speaker with a horn.

A horn (such as is generally used) about 2 ft. long, measured along the curved axis, will probably be resonant at about 50 p.p.s., roughly indicated by blowing across the small end. If a telephone is caused to emit a pure note it will be found that the increase in volume obtained by placing a horn on it is very much greater on low notes (say up to 400 p.p.s.) than on higher ones. On frequencies above about 1,500 hardly any change can be observed. Therefore when music consisting of a great number of frequencies is reproduced, not only will the volume increase on applying the horn, but also the tone will be altered considerably, and, if the loud speaker is properly made, considerably improved. The effect of the transformer, together with the high natural frequency of the diaphragm, will result in exaggerating the higher notes. The horn will bring out the lower notes more than the others, so tending to restore the balance.

If the diaphragm has a low natural frequency the addition of the horn will make matters worse.

Construction of Horn.

A simple conical horn will increase the

volume to a certain extent, but one of the familiar curved shape will give much better results, and can be made without much difficulty.

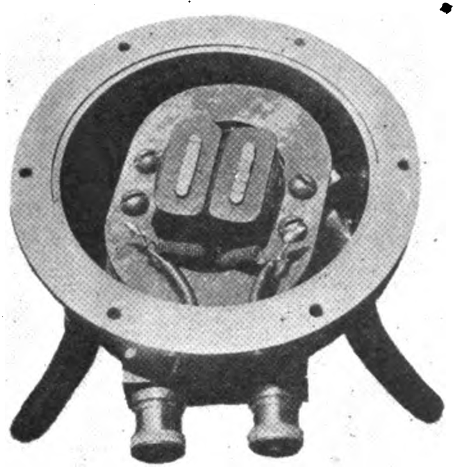


Fig. 2—Magnet and coils of iron diaphragm loud speaker.

Fig. 1 shows a horn made up of pieces of zinc soldered together, as described below. The bell-mouth consists of eight similar

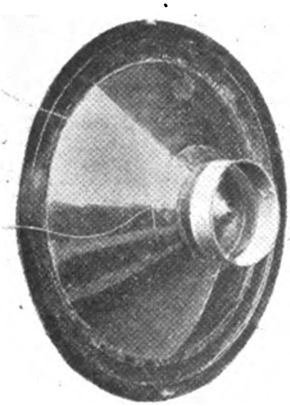


Fig. 3—Diaphragm and moving coil.

pieces, while the upright part is in one piece. These two parts present no difficulty. The pieces which go to make the right-angle bend are set out as follows :—

A wire frame is made to fit the octagonal smaller end of the bell, and another the shape of the larger end of the straight part, which is circular in section. The parts are then placed and held at the right position and angle relative to each other, while a wire is shaped so as to continue one of the corners of the bell-mouth down to the other part, as shown in Fig. 8. The other seven wires are also bent and soldered in place, giving a sort of outline of the bend. From this a paper pattern can be made of each piece by folding a flat sheet round each space and marking round with a pencil. Having made these patterns the horn may be completed. It should be quite strong and rigid, and in fact the writer's suffered no damage when the whole thing accidentally fell on the floor.

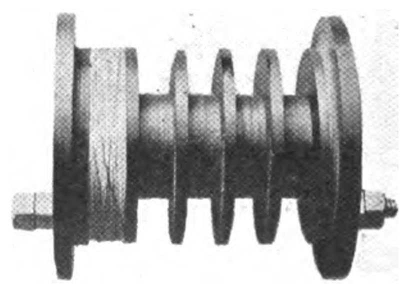


Fig. 4—Details of transformer.

This method of producing awkward parts can, of course, be applied to other shapes.

Suitable horns may also be purchased or made of paper pulp on a wax former, afterwards melted out. This type of horn is, however, somewhat messy to make, takes a long time to dry, and does not give a very good-looking horn, nor does it produce the same increase in volume as a smooth metal one does.

Construction of Moving Coil Instrument.

The field magnet consists of a bobbin $2\frac{1}{4}$ ins. diameter by $2\frac{1}{2}$ ins. long, wound full of No. 22 D.S.C. on a core $\frac{3}{4}$ in. diameter of soft wrought iron. A narrow air gap ·035 in. wide is left all round the top as shown, the top and bottom plates being

¼ in. thick (see Fig. 5). The magnetic circuit is closed through the tubular case.

The reluctance of the iron circuit (which determines the flux produced, and hence the force on the coil) will be proportional to the length of the gap, the reluctance of the rest of the magnetic circuit being negligible. Thus the flux would be halved weie a gap of ·07 in. left. To produce the same flux in this gap would need twice the current, which again would mean doubling the voltage—or four times the energy. A current of about ¾ amp. at 4 volts is used to energise the field.

Diaphragm and Coil Former.

These are both made from celluloid, cemented together with a solution of celluloid in amyl-acetate (see Fig. 3). Celluloid is ideal for the purpose, its S.G. being only about two-thirds that of aluminium. It is also possible to dispense with nuts and screws, resulting in absence ot rattle. The dimensions are given in Fig. 6. The coil must be exactly to size and perfectly round, and should be rolled on an ebonite rod turned exactly to size, and bound on with wire (without

Fig. 5—Showing air gap in the core.

removing the rod from the lathe) until the cement sets—this will take some hours—and then turned to size, after which it can easily be slipped off. It is wound with two layers of 44 s.s.c., about 80 turns, with a resistance of 16 ohms being got on. The wire should be embedded in celluloid cement.

Fig. 5 also shows the method of holding the diaphragm. A top plate with six 4 B.A.

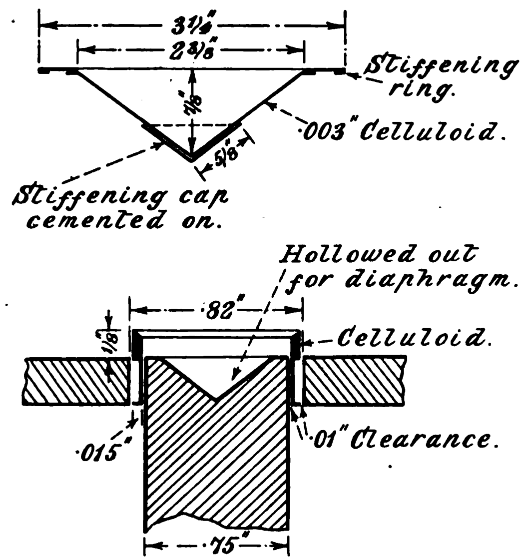


Fig. 6—Dimensions of coil and diaphragm.

screws holds it in place, and also carries the horn. The arrangement shown leaves room for adjusting the diaphragm into position, through the side, after the top has been put on.

A tubular brass case with three feet encloses the whole of the iron part up to the lower diaphragm ring.

Three terminals are provided, one to one end of the small coil, and one to one end of the field-coil, the other ends of both coils going to the middle terminal.

Transformer.

This loud speaker cannot be used without a transformer. If much power is to be used very considerable voltages may be set up across the primary when the plate current suddenly varies, probably more than that of the H.T. battery itself. For this reason, and to reduce the self-capacity, the primary is wound in five sections as shown in Fig. 4, the beginning of each section being taken down a small hole in the thickness of the ebonite wall. This will mean a joint at the bottom of each section.

A total of 11,000 turns of 40 s.s.c. are used

for the primary, after which a few layers of paper and shellac varnish are put on. The secondary, wound without sections, consists of 300 turns of 22 D.S.C.

The high insulation of the primary may be shown by joining the ends of the thick wire coil across a pocket lamp battery, when a

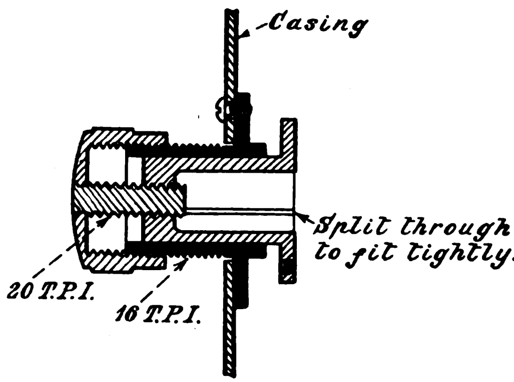


Fig. 7—Illustrating method of adjusting air gap.

spark up to $\frac{1}{8}$ in. will jump the ends of the other winding. An open core of iron wires, $\frac{5}{8}$ in. diameter, is employed.

This transformer can be replaced by an ordinary ignition coil, using the high resistance winding for primary; in this case, the diaphragm coil should be wound with two layers of No. 40 S.S.C.

Iron Diaphragm Loud Speaker—Adjustment of Air Gap.

The magnets and coils (see Fig. 2) are mounted on a round sliding piece, which is prevented from turning by its tight fit, but can be raised or lowered by a knurled head. The arrangement shown in Fig. 7, while somewhat elaborate, is rigid and capable of fine adjustment, the distance moved forward per revolution being the difference between the two pitches employed (1-16th in. and 1-20th in.) or 1-80th in.

When putting the instrument away for a time always close the air gap.

Windings.

No. 44 S.S.C. should be used, wound to a resistance of 1,500 ohms. Nothing is gained by winding to a higher resistance than this; in fact, if a low impedance valve (as the B.4) is used, practically equal results are obtained with the two coils in parallel—giving 375 ohms.

The cores of the bobbins are of welding iron, a very pure form of the metal. The wire is filed up square, and bent into L shape, using six pieces for each pole piece. The poles are $\frac{1}{8}$ in. wide, 11-16th in. long across the top and $\frac{1}{2}$ in. apart.

The diaphragm is of tinplate, with the tin wiped away while hot. It is $3\frac{1}{4}$ ins. diameter by ·012 in. thick.

Comparison between the Two Types.

These two loud speakers were both constructed by the writer, and gave the best results of many variations on both types The following notes as to their performance (on a resistance coupled amplifier without reaction) may be of interest as indicating what may be expected of similar apparatus.

The iron diaphragm loud speaker reproduces remarkably well in some directions, particularly a man's voice, or, say, a violin or flute solo. On orchestra music and the piano a certain flavour is introduced which ought not to be there, which renders it impossible to imagine that one is listening to the real thing. On rustling noises (such

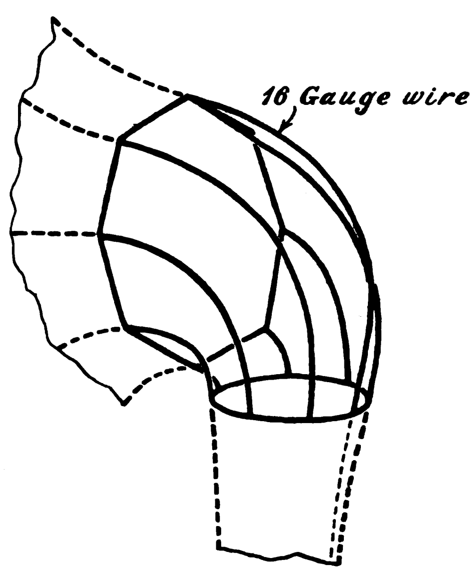


Fig. 8—Wire former for horn.

as "sea waves" recently broadcast) it shows up at its worst, being quite unrecognisable.

For all this, it is quite as good as the average commercial instrument of the same type.

The above defects are not so much due

to the horn as to distortion produced by the iron, and by the low natural frequency of the diaphragm. A fairly large diaphragm *must* be used if any volume is required.

The moving-coil type is capable of extremely good rendering of practically any music or speech. Comparative tests on the same horn show that in some circumstances the improvement is very marked.

The diaphragm with its coil of this loud speaker only weighs about 1½ grams, whereas an iron diaphragm of the same diameter weighs about six times as much. Due to the small mass the natural frequency is not nearly so well marked, and owing to the special shape employed, considerably over 1,000 p.p.s.

Except what occurs in its transformer, no iron distortion is present, since, although plenty of iron is used, the intensity of the field in the iron is maintained perfectly constant.

An instrument of this type can be worked so as to be audible at ¼ mile distant.

In spite of its superiority, the moving-coil type does not seem very popular. It is, of course, more expensive to buy, and requires a certain amount of power for its field. A certain residual magnetism remains on switching off the field current, and the instrument will work on this; on applying the field current the volume increases five to ten times. It is then giving much the same volume as would an iron diaphragm loud speaker, under the same conditions.

If it were thought worth while to fit the instrument with permanent magnets, six or eight bar magnets would replace the outer iron case, with their axes parallel to the central rod, which should remain of soft iron.

Use as a Microphone.

It is interesting to note that either of these loud speakers can be used as a microphone. They are, however, very inefficient in this respect. Speaking close to the horn only a very moderate strength of speech was obtained with a stage of L.F.

Using an ordinary 2,000-ohm earpiece without horn similar results are obtained with three stages of L.F. It is, therefore, rather surprising that the inventor of the telephone (who used it as both transmitter and receiver) could hear anything whatever with it. His instrument could only be a fraction as efficient as a present-day telephone, as would also be the telephone used with it, and no amplification was possible.

The Trend of Invention.

We summarise below the more important inventions which have been disclosed during the month; special reference being made to those of particular interest to the experimenter.

The Anson Relay.

The arrangement illustrated in Fig. 1 is now fairly familiar, its object being to improve the working of Morse relays by three-electrode valves (British Patent 214,754, H. St. G. Anson). The audio-frequency Morse signals are sufficiently amplified and impressed by means of a transformer on the grid of valve D. In the grid circuit of this valve is included a grid condenser C, with leak E, so that the signal currents depress the mean potential of the grid and cause a decrease in plate current. The interesting feature is the inclusion in the plate circuit of a neon lamp A in series with the relay B. The neon lamp acts as a suitable series resistance for reducing the time-constant of the relay circuit, at the same time steepening the response characteristic or sensitivity of the system. An ordinary ohmic resistance used in place of the neon lamp would reduce the time constant, but would flatten the characteristic.

Uranium as Cathode for Thermionic Tubes.

British Patent 207,514 (Western Electric Co., Ltd., and J. E. Harris) covers the use of the metal uranium for the electron emitting cathode in thermionic discharge tubes. It is stated that uranium has about the same emissivity as the alkaline earth oxide coated

filament, but has a relatively high melting temperature, and a relatively low rate of volatilisation, and retains its activity when subjected to high voltages. The form of tube illustrated in the specification is shown in Fig. 2. The cathode C consists of a molybdenum boat containing finely powdered uranium, the leads E and D being taken

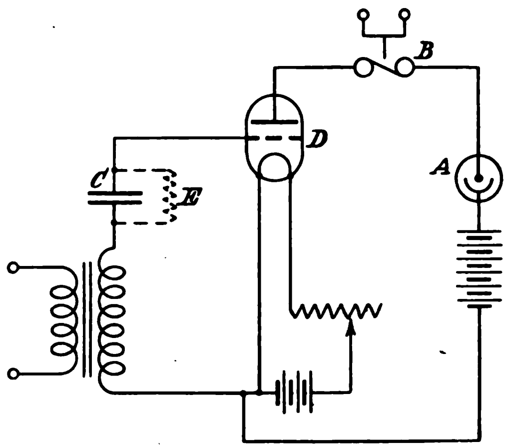


Fig. 1—The Ansu relay circuit.

through sub-divided seals to deal with the cathode heating current. The patent, however, covers the use of metallic uranium by itself or an alloy of uranium with another highly refractory element.

Improved Loud-Speaking Reproduction.

H. J. Round has evidently realised the extravagance of expecting one diaphragm and one circuit to do everything over the entire range of audibility, and has accordingly patented the use of two or more diaphragms having natural periods of vibration of different values, and actuated by separate magnet windings (British Patent 215,104, H. J. Round). The effects from the various diaphragms combine in one common horn of large dimensions. It is preferred to use a series of magnetophones of the type illustrated diagrammatically in Fig. 3, the case and central core of which form the magnetic circuit ; the large winding is used to produce the necessary magnetic field, while the small one is a light movable coil carrying the speech currents, and which actuates the diaphragm. The inventor states that good results for speech are obtained by the use of two magnetophones whose diaphragms have natural frequencies of 600 and 6,000 respectively. For music he recommends three of natural frequencies—200, 900 and 6,000—while better still is a combination of five diaphragms having frequencies of 200, 500, 900, 2,000 and 8,000 respectively. Systems of multiple amplifiers and filter circuits are described in the specification for the purpose of suppressing unduly prominent frequencies, and for ensuring the reproduction of the various frequencies in their right proportions.

Method of Repairing Valve Filaments.

Fig. 4 illustrates a process of renewing the filament in valves such as the R type, where the filament is horizontal (British Patent 215,437, J. M. Longe and P. V. Castell-Evans). The pip is first removed to release the vacuum, and through the hole thus made at F air is forced in from the tube E, while

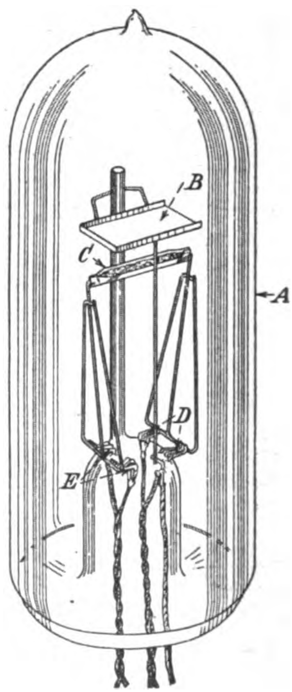


Fig. 2—A uranium cathode valve.

the points C are heated with a pointed blowpipe flame G. Two holes are thus burst in the glass at points C sufficient to allow the introduction of suitable manipulating tools. The tops of the vertical portions of the filament supports D are cut off, and removed along with the remains of the old filament. New tops to these supports are made and fixed,

as shown at H in the second figure, by forming their lower ends into spirals that will just fit over the remains of the old supports. When in position, the spiral portions are

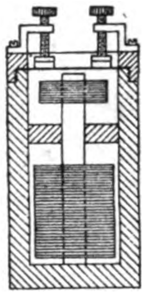


Fig. 3—Construction of the Round loud speaker.

pinched to secure them firmly in position. The new filament may be attached to the tops of these new supports before their insertion in the valve. The holes at C are sealed up again, and the bulb is evacuated through a tube sealed on at F.

Overcoming Mechanical Resonance in Telephone Receivers.

Most telephone diaphragms have a pronounced resonant frequency which results in

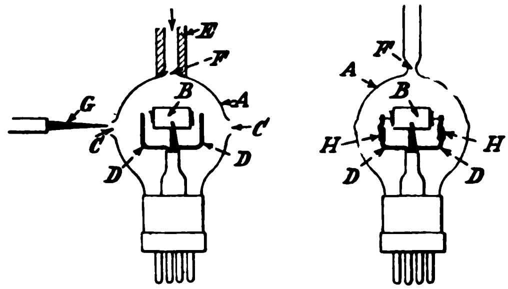


Fig. 4—Method of re-filamenting valves.

undue prominence in reproduced sounds of this frequency; this, in fact, is one of the commonest forms of distortion. J. Bethnod has patented the use of a rejector circuit in series with a telephone receiver, the rejector being tuned to the mechanical resonance frequency of the telephone diaphragm (British Patent 206,139, J. Bethnod).

Business Brevities.

A Legless Valve Holder.

The accompanying photograph illustrates a legless valve holder which has been produced by Messrs. Goswell Engineering Co., Ltd., of 12a, Pentonville Road, London, N.1. It will be seen that the holder is arranged so as to allow either panel or surface wiring to be employed. The connecting wires may be gripped by passing through the panel, allowing the ends to enter the sockets where they are gripped by the setscrews, or they may be fixed externally under the screw heads. We notice that the base of the sockets are level with the ebonite moulding which necessitates the holder being mounted on an ebonite panel. Perhaps it would have been advantageous to have countersunk the base of the sockets so that the holder could be mounted on a wooden or other panel, thereby increasing its use materially.

* * *

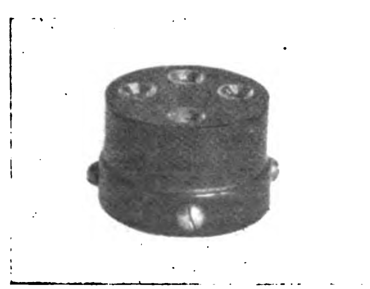
A New Mullard Resistance.

The Mullard Radio Valve Co., Ltd., have recently produced a very interesting type of filament rheostat. It consists essentially of a drum carrying the resistance wire arranged in a spiral form. The drum is caused to rotate by turning a knob which is fixed to a pointer arranged to operate over a spiral scale. The total resistance of the wire is about 8·8 ohms, and gives an exceedingly fine gradation of filament current. The price of the rheostat is only 4s. 3d.

* * *

Fallon Condenser Co., Ltd.

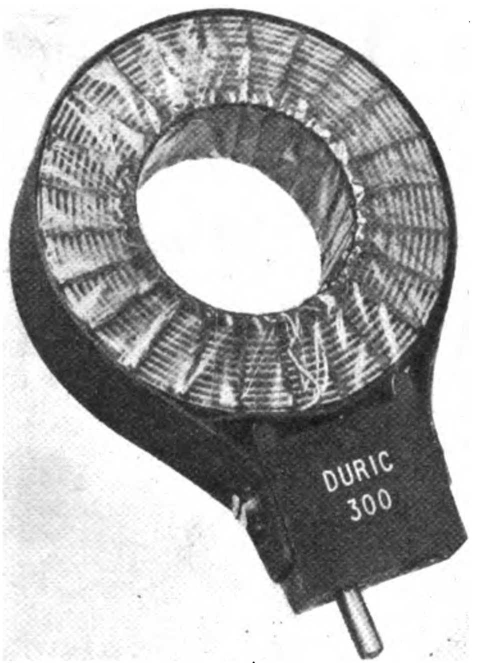
We are advised that Messrs. Fallon Condenser Co., Ltd., have just opened a city depôt at 143 Farringdon Road, London, E.C.4, where all their goods may be obtained, both wholesale and retail.



A legless valve holder.

"Duric" Inductance Coils.

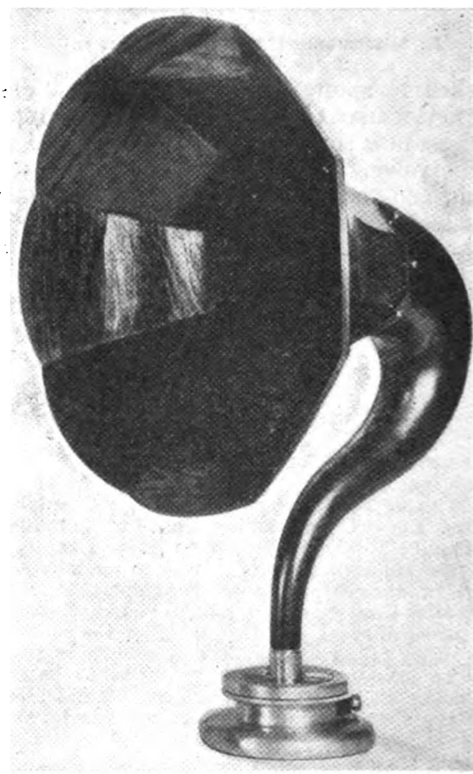
Messrs. Radio Acoustics, Ltd., have submitted to us a set of their new "Duric" plug-in coils, one of which is shown in the accompanying photograph. We find these coils electrically satisfactory, and the method of construction gives them a mechanical rigidity and durability which many other makes lack. Multi-layer winding is employed, the layers being air-spaced by means of separate spacing elements and not by means of the wire itself. The windings are bound with oiled-silk tape to protect them from the atmosphere. For general tuning purposes we find these coils at least as good as most other makes of plug-in coil. We have made special tests in our laboratory with the largest and smallest sizes (coils Nos. 500 and 30). With no external loading capacity the No. 500 coil tunes to 960 metres, and with a shunt capacity of ·001μF. it tunes to 7,800 metres, indicating a self-capacity of about ·000014μF., which is creditably low for a long-wave coil. The No. 30 coil has only two layers, tuning to 90 metres by itself and 540 metres with a ·001μF. condenser, indicating a self-capacity of about ·000028μF. Although this latter value is twice that for the large No. 500 coil, it compares favourably with other short-wave multi-layer coils that we have tested. Our tests indicate that the advantages of multi-layer winding are less for short-wave coils of few layers than for long-wave ones having a large number of layers.



The Duric Inductance.

The Allison Loud Speaker.

We have recently received from the Cromwell Engineering Co. one of their "Allison" loud speakers for purposes of test. It will be noticed that in appearance it is very similar to the well-known Amplion loud speaker but the construction is entirely different. The smaller photograph illustrates the construction and arrangement of the diaphragm and magnetic system. The strong permanent magnets and coils are rigidly fixed in the base chamber and are hermetically sealed by a good quality wax filling. The mounting of the diaphragm is of special interest. The diaphragm, which is of Stalloy, is rigidly fixed round the entire circumference to the top cover plate, which also serves to carry the horn. In operation the cover plate carrying the diaphragm and horn is screwed down until the diaphragm is at the correct distance from the magnet poles. It is claimed that this method of construction results in extreme rigidity and tends materially to improve the tone. On test we found the loud speaker both sensitive and mellow in tone, there being not the slightest trace of either harshness or shrillness. Several models are made, fitted with aluminium, mahogany or oak horns and the prices range round £4 or £5 according to the size of horn and resistance of the winding. The address of the Cromwell Engineering Co. is 81, Oxford Avenue, Merton Park, S.W.20.



The Allison Loud speaker.

WATMEL WIRELESS CO.

Messrs. Watmel Wireless Co. advise that owing to increased business they have been compelled to move into much larger premises which are now situated at 332A, Goswell Road, London, E.C.1.

* * *

"CLIX."

Readers will be pleased to learn that Messrs. Autoveyers, Ltd. have now been able to revise the retail price of their ever popular and useful Clix as follows:—Clix, with locknuts, 3d. each; Clix insulators (six colours), 1d. each; Clix bushes (six colours), 1d. pair.

The Allison Diaphragm.

Recent Wireless Publications.

Figures after the title of each publication indicate Volume and Number of Publication containing the article. Where only one number is given, this indicates the serial number of the publication. The abbreviations used in this bibliography will be found in the early issues of "Experimental Wireless."

I.—TRANSMISSION.

DIRECTED RADIO RAYS.—Prof. René Mesny (*R. News*, 5, 12).

ZIEHVORGÄNGE IN INDUKTIV GEKOPPELTEN ZWISCHENKREISRÖHRENSENDERN. — Wilhelm Runge (*Jahrb. d. drahtl. Tel.*, 23, 1).

TYPISIERUNG VON DREIELEKTRODENRÖHRENSENDERN.—H. Wigge (*Jahrb. d. drahtl. Tel.*, 23, 1).

VERSUCHE ÜBER TELEPHONIE MIT DOPPELGITTERRÖHREN.—A. Hamm (*Jahrb. d. drahtl. Tel.*, 23, 2).

DIE MASCHINELLE FREQUENZ - MULTIPLIKATION - SANORORDNUNG VON W. DORNIG.—Eugen Nesper (*Jahrb. d. drahtl. Tel.*, 23, 2).

THE DEVELOPMENT OF SIMULTANEOUS BROADCASTING.—E. K. Sandeman, B.Sc. (*W. World*, 250 and 251).

BROADCASTING DISTRIBUTION.—R. Brown and G. Gillett (*Electn.*, 2,403).

PRACTICAL MASTER OSCILLATOR SETS.—E. A. Laport (*Q.S.T.*, 7, 11).

A GOOD BREAK-IN SYSTEM.—P. Laskowitz (*Q.S.T.*, 7, 11).

SMALL TRANSFORMERS FOR THE AMATEUR.—H. F. Mason (*Q.S.T.*, 7, 11).

THE EFFECT OF THE SERIES CONDENSER IN A TRANSMITTING AERIAL.—E. H. Robinson (*Exp. W.*, 1, 9).

II.—RECEPTION.

POUR RECEVOIR LES ONDES TRÉS COURTES.—M. Malgouzou (*L'Onde Elec.*, 27).

L'INFLUENCE DU BROUILLAGE SUR LES RÉCEPTEURS A RÉACTION.—L. Brillouin and E. Fromy (*L'Onde Elec.*, 28).

L'AMPLIFICATEUR H.F. À RÉSISTANCES ET LES ONDES COURTES.—M. P. Lafond (*L'Onde Elec.*, 28).

QU'EST-CE QU'UN COLLECTEUR D'ONDES ?—Michel Adam (*R. Elec.*, 5, 60).

GÉNÉRATEUR - AMPLIFICATEUR SANS LAMPE. — I. Podliasky (*R. Elec.*, 5, 60).

SUR LA THÉORIE DU RÉCEPTEUR TÉLÉPHONIQUE.—J. Bethnod (*R. Elec.*, 5, 61).

EINE NEUARTIGE RUCKKOPPLUNG BEIM VIERRÖHREN-HOCHFREQUENZ-VERSTÄRKER.—W. Hey (*Jahrb. d. drahtl. Tel.*, 23, 3).

ÜBER STÖRUNGEN BEIM RADIO-EMPFANG.—E. Lübcke (*Jahrb. d. drahtl. Tel.*, 23, 3).

A NEW THEORY OF CONTACT DETECTORS.—James Strachan, F.Inst.P. (*W. World*, 250).

PUSH-PULL SPEECH AMPLIFIER.—W. James (*W. World*, 251).

OSCILLATING AND AMPLIFYING CRYSTALS.—Hugh S. Pocock (*W. World*, 252).

SHORT-WAVE RECEIVER.—(*W. World*, 252.)

THE TUNED CATHODE CIRCUIT.—J. F. Johnston (*W. World*, 253).

THE SENSITIVITY AND PHYSICAL PROPERTIES OF CRYSTALS.— James Strachan, F.Inst.P. (*W. World*).

BUILDING SUPERHETERODYNES THAT WORK.—Part I (*Q.S.T.*, 7, 11).

A FOUR-ELECTRODE VALVE RECEIVER.—G. L. Morrow (*Exp. W.*, 7, 11).

SUPERSONIC RECEIVER EMPLOYING A FOUR-ELECTRODE VALVE.—A. L. Williams, R.N. (*Exp. W.*, 1, 9).

DIRECTION FINDING.—Commdr. J. A. Slee (*Exp. W.*, 1, 9).

III.—MEASUREMENT AND CALIBRATION.

DIE MESSUNG DER SCHEITELSPANNUNG MIT DER GLIMMRÖHRE.—A. Palm (*Jahrb. d. drahtl. Tel.*, 23, 1).

CHECKING UP ANTENNA FORMULAS.—Ralph R. Batcher (*Q.S.T.*, 7, 11).

IV.—THEORY AND CALCULATION.

SUR PLUSIEURS EXTENSIONS DE LA NOTION DE RÉSISTANCE.—Lieut. Blanchard (*L'Onde Elec.*, 28).

ZUR BERECHNUNG KOMBINIERTER SCHWINGUNGSKREISE.—G. Kuprijano and P. Schmakow (*Jahrb. d. drahtl. Tel.*, 23, 1).

DIE RESONANZKURVEN BEI VERSCHIEDENEN DÄMPFUNGSTYPEN.—D. Roschansky (*Jahrb. d. drahtl. Tel.*, 23, 2).

BERECHNUNG DER KOPPLUNGSKOEFFIZIENTEN FÜR EINIGE BENSÖNDERE FÄLLE DER GEGENSEITIGEN INDUKTION.—D. Wicker (*Jahrb. d. drahtl. Tel.*, 23, 2).

NAGAOKA'S CORRECTION FACTOR K.—E. J. Hobbs, M.C. (*W. World*, 250).

GRID RECTIFICATION.—J. H. Reyner, B.Sc. (*Exp. W.*, 1, 9).

V.—GENERAL.

OBSERVATIONS RADIOÉLECTRIQUES.—(*L'Onde Elec.*, 27.)

L'ANTENNE ONDULATOIRE OU ANTENNE BEVERAGE.—M. F. Bedeau (*L'Onde Elec.*, 27).

LA STATION RADIOTÉLÉGRAPHIC DE MOSCOU-HODINSK.—(*L'Onde Elec.*, 28).

THE VACUUM TUBE AND HOW IT WORKS.—Prof. J. H. Morecroft (*R. News*, 5, 12).

LOOSE-COUPLED TRANSFORMERS.—(*W. Trader*, 2, 16.)

CORRECTION DE LA DISTORTION DUE À LA CAPACITÉ DE CABLES TÉLÉPHONIQUES, DES AMPLIFICATEURS ETC.—I. Podliasky (*R. Elec.*, 5, 61).

DIE QUECKSILBERLAMPE ALS FUNKENSTRECKE UND UNTERBRECHER.—W. Burstyn (*Jahrb. d. drahtl. Tel.*, 23, 1).

ZUR BESTIMMUNG DER KURVENFORM VON WECHSELSTRÖMEN MIT HILFE DER BRAUNSCHEN RÖHRE.—L. Casper, K. Hubmann and J. Zenneck (*Jahrb. d. drahtl. Tel.*, 23, 2).

ÜBER ERZWUNGENE SCHWINGUNGEN IN GEKOPPELTEN ELEKTRONENRÖHREN KREISEN.—F. Rossmann and J. Zenneck (*Jahrb. d. drahtl. Tel.*, 23, 3).

DER EINFLUSS EINER LEITENDEN VERBINDUNG VON ZWEI GEKOPPETEN KREISEN.—F. Rossman and J. Zenneck (*Jahrb. d. drahtl. Tel.*, 23, 3).

DAS VERHÄLTNIS VON INDUKTIVER UND DIREKTER KOPPLUNG.—F. Rossman and J. Zenneck (*Jahrb. d. drahtl. Tel.*, 23, 3).

FAITHFUL REPRODUCTION BY BROADCAST.—Capt. P. P. Eckersley, M.I.E.E. (*W. World*, 250 and 251).

THE CHEMISTRY AND MINERALOGY OF CRYSTALS.—J. Strachan, F.Inst.P. (*W. World*, 251).

THE EARLY HISTORY OF TELEVISION.—J. Strachan, F.Inst.P. (*W. World*, 252).

AN ALTERNATIVE TO THE HEAVISIDE LAYER THEORY.—Prof. G. W. O. Howe (*Electn.*, 2,404).

ÜBER DIE BESEITIGUNG DER WECHSELSTROMPARASITEN BEI GLEICHSTROM - VERSTÄRKER - RÖHREN.—H. Greinacher (*Zeitschr. f. Physik.*, 23, 6).

ÜBER DIE REFLEXION UND BRECHUNG ELEKTRISCHER WELLEN AM GESCHICHTETEN MEDIUM.—K. Försterling (*Ann. d. Physik.*, 74, 2).

DAS VERHALTEN HERTZSCHER.—Clemens Schæfer (*Ann. d. Physik.*, 74, 3).

ON THE EMISSION OF POSITIVE IONS FROM HOT TUNGSTEN.—Prof. W. A. Jenkins (*Phil. Mag.*, 281).

TELEPHONE DIAPHRAGM RESONANCES.—Prof. E. Mallett, M.Sc. (*W. World*, 253).

A NEW RADIO SIGNALLING SYSTEM.—Paul B. Findlay (*Q.S.T.*, 7, 11).

THE UTILITY OF THERMIONIC VALVE CHARACTERISTICS.—H. J. Barton Chapple, B.Sc. (Hons.) (*Exp. W.*, 1, 9).

VALVE MANUFACTURE.—W. J. Jones, B.Sc. (*Exp. W.*, 1, 9).

THE HEARTSHAPE.—F. Youle, B.Sc. (*Exp. W.*, 1, 9.)

THE PROBLEMS OF HIGH-TENSION SUPPLY.—R. Mines, B.Sc. (*Exp. W.*, 1, 9).

Correspondence.

Letters of interest to experimenters are always welcome. In publishing such communications the Editors do not necessarily endorse any technical or general statements which they may contain.

To the Editor of EXPERIMENTAL WIRELESS.

DEAR SIR,—In the letter from "Kilo Watt" in the present issue of EXPERIMENTAL WIRELESS mention is made of sparks being drawn from an aerial during rain or hail. In this connection I should like to mention that one of my aerials runs towards a railway line at the end of the garden, and while it was connected to the receiver (it is usually used only for transmission) I heard a very loud noise when a train passed. Later, when the receiver was switched off, I heard clicks coming from it, which proved to be due to sparks passing across the series condenser; any number up to about a dozen or more were caused by the passing of a train. On disconnecting the aerial altogether and bringing my finger near it a brush discharge started at about ⅛ in., and about ⅛ in. spark could be obtained. The most favourable occasions are dry days when the steam from the engine is evaporated very rapidly. It is not necessary for the smoke, etc., actually to pass against the aerial.

The action of this effect seems to be similar to that of the hydro-electric machine, consisting of an insulated boiler, which becomes charged to a very high potential when steam is blown off, and presumably any insulated wire near-by would receive a charge of opposite sign.

Perhaps some other readers have noticed an effect of this sort, and would be interested to compare results.—I am, faithfully yours,

MARCUS G. SCROGGIE.

To the Editor of EXPERIMENTAL WIRELESS.

DEAR SIR,—With regard to the correspondence in the last two issues of this journal concerning spark discharge from aerials, I concur with the opinion that hailstorms apparently charge an aerial to a higher P.D. than anything else. To quote my experiences :—

Two cases came to my notice of sparks being obtained from an aerial during a heavy rainfall, but they were quite small.

However, on April 12, 1924, I distinctly obtained sparks from an aerial 100 ft. long by 40 ft. high (single wire).

I discovered the presence of an unusual charge through the medium of a gentleman (who was using the aerial at the time) receiving a very appreciable shock.

On holding the end of the "lead-in" near the earth terminal a spark about an inch in length occurred, accompanied by the characteristic crack associated with spark discharge. This was loud enough to be heard plainly in a large room, in which a number of persons were talking.

After this one large spark others were obtained, of decreasing length, for the space of two minutes or thereabouts.

A heavy hailstorm had occurred previously, and at the time of obtaining the sparks a low-lying cloud was passing overhead.

I also have tried to obtain sparks during many thunderstorms, but without success, although loud crackles are heard in the 'phones as the lightning stroke occurs.

This subject seems to be raising an interesting point, and I hope somebody will come along with some actual measurements.—Yours faithfully,

D. C. W. JOWERS.

To the Editor EXPERIMENTAL WIRELESS.

DEAR SIR,—I should be glad if you would allow me to reply to Mr. Hogg's letter. I fear that Mr. Hogg has never, or at any rate does not usually, employ loose coupling. That, I think, is his chief trouble. His chief grouse against variometers seems to be their unselectivity.

Surely it is better to get our selectivity in the aerial, or at any rate the secondary, circuit. He admits that a greater amplification is obtained. If, then, the grid circuit of the H.F. valve is made selective (of course, this cannot be done efficiently with a direct-coupled set) then no trouble will be found with the variometer and better amplification obtained than by sacrificing amplification to selectivity in the tuned anode coil. Another advantage incidentally of loose coupling is that hand capacity, of course, disappears, as a parallel condenser may be used in the aerial and secondary circuits.

Having described his own set, Mr. Hogg then makes the amazing statement that L.F. amplification decreases the selectivity of a set. What the L.F. amplifier has to do with the aerial or tuned anode circuits beats me, unless, of course, Mr. Hogg used a reflex with a L.F. transformer in the aerial circuit, as I saw in a magazine the other day. As regards Mr. Hogg's statement that a circuit using resistance-controlled regeneration causes oscillation trouble, I suppose he must have his little joke. Surely a resistance cannot make the set radiate more than if the regeneration was controlled in the conventional manner. I suggest that his neighbour has excessive H.T. on his H.F. valve.—Yours faithfully,

H. ANDREWES.

To the Editor of EXPERIMENTAL WIRELESS.

DEAR SIR,—An Erla Transformer has been sent to me by the Electrical Research Laboratories of Chicago for testing. A preliminary examination of the transformer showed that it was of neat appearance and well made. On testing it the tone was found to be extraordinarily good even when used in the third stage of amplification and the volume compared well with the majority of British transformers. The core although very simply and easily made is perfectly satisfactory. The ohmic resistance of the primary winding is 1050 ohms and of the secondary winding 6300 ohms. The transformer ratio is one to three and a half. The insulation resistance of primary to secondary is infinite, or windings to case 300 megohms and of windings to core infinite. The reason for the low resistance between windings and case is probably due to the fact that the terminals are set in the top of the casing and the methods of insulation are perhaps a trifle insufficient. The impedance of the transformer was not tested for various frequencies. The price of the transformer (5 dollars) is a little high compared with the majority of British transformers but there is no doubt that it gives excellent results. Perhaps the above results of my tests may be of interest to some of your readers.—Yours truly,

BRIAN H. COLQUHOUN (2QZ).

MISUSE OF CALL SIGNS.

To the Editor of EXPERIMENTAL WIRELESS.

DEAR SIRS,—I noted Mr. Hay's letter in your issue of April 30 last but think he must have made a slight mistake.

The call sign Radio 2KG (two kg) was allotted to my station in December of last year so I presume that Mr. Hay has for some reason or other failed to comply with G.P.O. regulations.

Before people rush into Press regarding such matters I should have thought it more diplomatic to approach H.M. Postmaster-General to ascertain whether he might have erred in issuing duplicate call signs and incidentally give him the opportunity of correcting same or dealing with the delinquent.

I would remind Mr. Hay that the call sign is the property of the Post Office, and I fail to see what legal redress he has in the matter, beyond protection from the issuing authorities.

I would compliment him, however, on his direction finder which appears to be of the 99½ per cent. efficiency type.—Yours faithfully,

GEO. K. FIELD (Major),
Chartered Electrical Engineer.

To the Editor of EXPERIMENTAL WIRELESS.

DEAR SIR,—Recently I have received reports from the North of England stating times of receiving my station during the majority of which I have been able to prove that I was not working. It appears

therefore that some experimenter unknown has taken to himself the authority to make use of my call sign. May I, through the medium of your columns, draw attention to this fact in the hope that the individual or individuals concerned may note that I am aware of this use of my call sign and consequently discreetly forego taking such liberties? May I also point out that should I receive any further intimation of the unauthorised use of my call sign I do not intend to allow the matter to remain unattended?—Yours faithfully,

BRIAN H. COLQUHOUN (2QZ).

Experimental Notes and News.

The French Government has not been slow in making use of wireless to open up communication with its African colonies. A station at Saigon has been working for several months, and on June 10 one was opened at Bammako, on the Niger, which puts French West Africa in direct communication with France. Two other stations are planned, one at Brazzaville, on Stanley Pool, and one at Antananarivo (Madagascar).

* * *

The first ship to carry the new type of Marconi installation for ships' lifeboats, including a directional receiver and sense finder, is the P. & O. steamer *Majola*. This apparatus has been specially designed for use under the most adverse weather conditions, and in very confined space. The transmitter is capable of attracting the attention of a ship using a crystal detector at a distance of fifty miles, and at greatly increased distances if the ship is fitted with valve receivers. The directional properties of the receiver enable the lifeboat crew to ascertain the bearing of other ships.

* * *

Reception from the transmitting station at Teviot Place, Edinburgh, has considerably improved as a result of the visit of Mr. H. L. Kirke, the B.B.C. development engineer. It was found that the transmitting aerial was partially screened by surrounding buildings. The unscreened portion was accordingly extended, and reports show a great increase in the strength of reception.

* * *

Complaints have been made that naval wireless signalling interferes with broadcasting near naval stations, with the result that the Admiralty may reduce the destroyer wave-length, which, in home port areas, is now 310 metres. Orders have already been given at Portsmouth that signalling between 7 o'clock and 10.30 each evening is, as far as possible, to be avoided.

* * *

On Friday, June 13, the first message was transmitted by Signor Marconi's wireless beam system to the Argentine, a communication being sent by Senor Le Breton, Minister of Agriculture to the Republic, to General Justo, Minister of War. This opens up the possibility in the near future of a direct telegraphic service to the South American Republics, ensuring the delivery of messages within a few minutes of their transmission.

Mr. J. W. Riddiough asks us to announce that the address of his experimental station 5SZ is now White Croft, Bare Lane, Morecambe, Lancs.

* * *

Mr. John McLaren, of Dalriada, Worthing, has been allotted the call sign 5AO. This call sign was previously held by Mr. H. H. Elsom, of Birmingham.

* * *

An interesting experimental wireless trip has recently been carried out from Australia. Mr. C. D. Maclurcan sailed from that country for America, with the object of carrying out wireless tests in connection with long-distance transmission on low waves and comparatively low power. A complete low-power wireless installation was fitted up on board R.M.S. *Tahiti*, with special aerials and counterpoise systems. Before the voyage considerable uncertainty had prevailed in Australia regarding the reception in America of signals transmitted by Australian amateurs. Sydney amateurs and experimenters in other States reported regularly the reception of American messages, but no reports came from America acknowledging the receipt of Australian signals. A strict checking method was employed to confirm all claims of reception, and messages were picked up all the way to San Francisco. The trip proved conclusively that the fault lay with the American amateurs, who have a great deal of interference to contend with. Moreover, the American is not so used to receiving weak signals as the Australian, and there is little incentive for him to "reach out." The Australian Government does not allow the use of much power, and accordingly amateurs in that country must rely upon increased efficiency. In America transmitters use far greater power. Mr. Maclurcan mentioned one station which was rated at 250 watts, but which actually used over 6,000 watts!

* * *

At the Annual General Meeting of the British Broadcasting Company, held on Wednesday, June 18, a resolution was adopted to the effect that from July 1, 1924, there should be one uniform licence fee of 10s., so that whether a listener was buying a complete set, or making up a set from parts, he should pay the same fee. The meeting also approved the proposal to abolish all tariffs and the passing of sets by the Post Office. This left only one restriction—that against the use of foreign parts—and at the end of the year that also would be removed.

Experimental Wireless

A JOURNAL OF RADIO RESEARCH AND PROGRESS

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Experimental Topics.

The Mechanics of Components.

IN conversation with one of our readers just recently, we were rather interested to hear him say, " Why do you publish articles on the construction of components ? I do not want to make switches or condensers. Why not use the space for more experimental matter ? " This is a perfectly fair comment, but it represents the viewpoint of an individual ; we should be interested to know what our readers think generally as to the type of article they like best. We were induced to take up the subject of mechanical construction because, in so many of the home-made instruments sent to our Laboratory for calibration, we found evidence of a total lack of knowledge of constructional principles and methods. An instrument may be perfectly designed from an electrical point of view, but if it is deficient in mechanical construction it gives very poor service. Not only is it likely to work badly through defective joints, or contacts, or bearings, but it must have a short life, and must ultimately be scrapped because of the constant trouble it gives, or even because it eventually falls to pieces. There is always a pleasure in using a well-made article, and we could not help feeling that many of our readers would get much greater pleasure from their radio experimenting if we could assist them to make their components correctly and well.

Wireless experimental work is broadening so rapidly in its field of interest that the needs of our readers so far as technical advice or assistance through our pages is concerned are bound to vary. One reader may be wholly interested in transmission problems ; another in reception, and so on, and so far as we are concerned editorially we endeavour to divide the space at our disposal as fairly as possible. We are always glad to have opinions or suggestions as to the type of matter most likely to be helpful, and if we took a general vote we feel quite sure that our articles on " The Mechanics of Components " would not be entirely unapproved.

Short-Wave Transmission.

In a paper read before the Royal Society of Arts on July 2, Senatore G. Marconi, G.C.V.O., LL.D., D.Sc., disclosed the result of considerable experimental work which he has been conducting with Mr. C. S. Franklin for some time past. The paper was essentially of a statistical nature and practically summarised the course of development since the year 1916 when the investigation of short waves was taken up in Italy. It is somewhat interesting to study the course of events as outlined in Senatore Marconi's paper. Investigation was first commenced with the idea of providing a directional system, and this obviously pointed to the use of reflectors which in turn necessitated the use of very short waves in order that the size of the reflectors might be kept within reasonable limits. Preliminary experiments seem to have been encouragingly successful and further investigation was accordingly conducted along the same lines but with a considerable increase in power. These experiments which took place in 1919 showed

that the received signal strength was approximately 200 times as weak when the reflectors were removed, which indicated that the reflectors actually functioned in the desired manner. The input was then gradually reduced and the reflectors replaced, it being found ultimately possible to establish communication over a very great distance with an absurdly small power. More experiments were undertaken in the early part of last year and some very peculiar results were obtained. Amongst other things, it was proved that the coefficient of the Austin-Cohen formula did not hold for very short waves, that the night ranges were considerably greater than expected, and that the presence of any intervening land had no appreciable effect on the propagation of the waves. In concluding his paper Senatore Marconi described how on May 30 of this year they succeeded in transmitting telephony to Australia on 92 metres with an input of 28 kilowatts. It is somewhat unfortunate that Senatore Marconi did not disclose any details of the apparatus which was used, or the circuital arrangements which were employed, but perhaps this was not possible for commercial reasons. What strikes us more forcibly, however, is the fact that no explanation whatever was offered which will account for the observed facts. The statistics given when compared with those relating to any ordinary long-wave station are certainly striking and to the lay mind may easily appear revolutionary. Such, however, is not really the case as the actual signal intensity at these high frequencies is probably capable of very easy explanation. The relation of signal strength to the sun's altitude, the deviation from the Austin-Cohen formula and the absence of appreciable fading to which Senatore Marconi referred in his paper are certainly subjects which require further investigation. Moreover, they are surely not beyond the field of amateur experimental work and it is hoped that perhaps several amateurs may be able to co-operate successfully in some useful research work. So far as the results which Senatore Marconi attained are concerned, communication with America on a power of 12 kilowatts should not frighten several British amateurs who regularly worked America and Canada last winter on a power of only 30 *to* 50 *watts*. It is probably safe to prophecy that some lucky enthusiast will be working regularly on speech to America with very little more power, before next season's tests are completed, but then let us hope that some very definite facts may be deduced from his experiments.

Broadcasting and Spark Interference.

We are very interested in some correspondence which has recently passed between the Postmaster-General and the Radio Association, who have asked us to bring the subject before the attention of our readers. It appears that many broadcast listeners have complained of considerable interference to reception owing to constant working of ship traffic. The Radio Association have written to the Postmaster-General on their behalf, and have enquired if he is in a position to take any steps necessary to minimise the interference. In their communication they suggested that it might be possible to reduce considerably ship transmissions between the hours of 8 and 11 p.m. The Postmaster-General's reply is very illuminating, as it not only shows his attitude towards broadcasting in its relation to wireless telegraphy, but also serves to indicate the lines upon which ship traffic is likely to develop within the next ten years. The use of the 300 and 600 metre wave for ship-to-shore traffic is permitted by the International Convention governing radiotelegraphic services, and he points out that so long as both British and foreign ships are equipped with spark apparatus, the maintenance of suitable spark stations on shore for the purpose of communicating with ships is imperative. On the other hand, it is pleasing to note that a large and increasing number of the more important liners are transmitting all their traffic by continuous waves and there is every indication that a more extensive use of the system is likely to become general, with, of course, greater freedom from jamming. In concluding his reply, the Postmaster-General adds that he has good reason to assume that much interference is caused by the use of flatly-tuned receivers, and suggests that much improvement could be effected. Our own experience confirms this view, and we hope that our readers may prevail upon their broadcast friends to realise not only the importance of ship traffic, but also the need for selective receivers.

Receiving Aerials of Low Resistance.

By N. W. McLACHLAN, D.Sc., M.I.E.E., F.Inst.P.

It is probable that many experimenters do not consider the effect of the ohmic resistance of their antenna systems on reception, this subject being fully dealt with in the following article.

THE influence of a low decrement receiving circuit on a radio-telegraphic signal of square formation is to transform it into one akin to that illustrated in Fig. 1 (*b*). The initial and final stages of the morse character, *i.e.*, the growth and decay epochs, are somewhat similar respectively to those obtained (1) when a circuit is completed containing a battery and a constant inductance of relatively low resistance (large L/R); (2) when the inductance is short-circuited upon itself after the current due to the battery has attained a definite value.* An

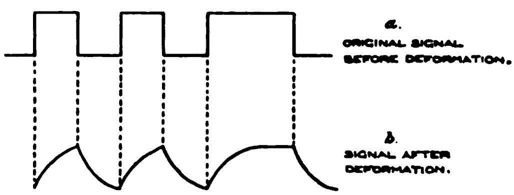


Fig. 1, a and b—Diagram showing the mis-shaping due to transmitting or receiving circuits of low decrement. Curve (b) represents the upper envelope of the audio frequency oscillations.

experimental arrangement facilitating these operations is depicted in Fig. 1 (*c*), in which a key or a relay with a back stop is used. If the relay is operated to give the letter "u" in the morse code, the relationship between current and time is of the form exhibited in Fig. 1 (*b*). In the case of a radio receiver, curves of this nature represent the upper "*envelope*" of the oscillatory current of radio- or audio-frequency. If these radio-frequency waves were rectified, the result would not be the envelope of Fig. 1 (*b*), and in certain respects curves of this class, when applied to oscillatory currents, may be misleading. The curve obtained from the morse signal after rectification and the customary smoothing process, will depend, amongst other things, upon the shape (curvature) of the rectifier characteristic. Moreover, in the process of rectification prior to utilising the resulting unidirectional varying current for operating a recording apparatus, we can encounter distortion which is superposed on that introduced by low decrement circuits. Under certain conditions, however, such distortion may be beneficial, since—when a three-electrode valve is set well back on its rectifying point—it tends to give the signal in the recording circuit a more rectangular profile. In fact, *in the absence of atmospheric disturbances* it is possible to obtain *recorded* signals of square formation which, owing to the "ringing" of the circuit,* are aurally unreadable. This is accomplished by setting one or more of the recording valves well back on their rectification points, as illustrated in Fig. 2.† This diagram shows the shape of the signal applied to the grid and the anode current corresponding thereto. It will be evident

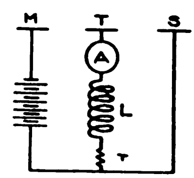


Fig. 1c—Circuit for illustrating "mis-shaping." T is a contact which moves alternately from contact M to contact S.
L = Large inductance.
r = Resistance of L $\frac{L}{r}$ is large.
A = Instrument to indicate current changes.

that the signal is more rectangular in shape *after* than before rectification. An effect of

* The damping factor of an inductive circuit is L/R, whereas that of an oscillatory circuit is L/2R.

* See EXPERIMENTAL WIRELESS, April, 1924, p. 401.

† In Fig. 11, *Journal I.E.E.*, vol. 61, p. 903, 1923, the valve V_2 would be given extra grid bias by augmenting battery B_2.

like nature can be obtained by setting one of the note magnifying valves well back on its rectification point. The action of the valve on the audio-frequency signals is similar to that illustrated in Fig. 2, and a highly-rounded and unreadable signal has its beginning and end clipped, thereby being rendered fairly intelligible in a telephone headpiece.*

Pursuing the problem of low decrements (supertuned circuits) still further, we may consider what happens when a circuit has zero *ohmic* loss. In surveying this side of the subject, we are reminded of the super-conductivity experiments of Kamerlingh-Onnes.† By immersing a lead spiral in liquid helium at a temperature about 2 degs. above absolute zero ($-271°$ C.), the conductivity was augmented 2×10^{10} times that at ordinary temperatures, and a unidirectional current in the spiral took one and a half days to decay to half its initial value. Superficially it would seem that the reduction in current was due entirely to the usual ohmic influence. This, however, is by no means true. Whenever the current varies in an inductive circuit, electro-magnetic energy is radiated into space. Moreover, a certain fraction of the energy loss in the lead spiral was caused by radiation. The spiral can therefore be considered to possess an auxiliary resistive quality, which for convenience is usually termed the "radiation" resistance. Under the peculiar conditions stipulated here, the value of the radiation resistance would vary with the current. When the current is a varying unidirectional one, the radiation resistance will be correlated in some manner with the rate of change of the current. In analytical language the radiation resistance will be a function of the current and the time, *i.e.*,

$r_a \times f^1(i) = \frac{d}{dt} f\ (i)$. Owing to the variation in the total resistance of the circuit (radiation plus ohmic, the latter being assumed constant), the value of R/L will depend upon the current, or more accurately on its rate of change. The relationship between current and time will therefore depart in some measure from the customary exponential equation $i = \mathrm{I}e^{-\mathrm{R}t/\mathrm{L}}$, owing to inconstancy of R/L.

After this preamble, the action of an aerial circuit of zero ohmic loss can be treated. So long as the aerial carries an oscillatory current, energy is radiated into space, and the circuit has a so-called radiation resistance. For a given open aerial this quantity increases as the square of the frequency, *i.e.*, it is augmented by accelerating the rate of change of current. *When the frequency is constant* an approximate formula for a certain class of aerial is $r_a = kh^2$, where k is a constant and h is the effective height of the aerial. The latter quantity depends upon the geometrical configuration, the loading inductance, shortening condenser and the influence of the ground and of neighbouring structures—aerial or otherwise. Now the frequency of a sinusoidal alternating current is constant and single valued during the "steady state." The amplitude is also constant. During the transient epochs, at the beginning and end of a morse character, the foregoing conditions are violated in the aerial circuit. The varying alternating currents can then—during growth and decay—be resolved into frequency spectra,* just as composite "white" light can be analysed into its constituents by a spectroscope. The principal frequency, *i.e.*, that of major importance, is numerically equal to that during the steady state. Owing to variation in frequency during the transient epochs—or more accurately to the fact that many frequencies are present—there will be a corresponding variation in the radiation resistance. With a circuit of adequately low decrement it is probably permissible for present purposes to disregard the variation in radiation resistance. Accepting this elementary hypothesis, the transients will take the exponential forms—

(a) $i = \mathrm{I}\ (1 - e^{-at} \sin \omega t)$ (growth)

(b) $i = \mathrm{I}e^{-at} \cos \omega t$ (decay)

where $\omega = 2\pi n$, $a = r_a/2\mathrm{L}$, r_a being the radiation

* The rectifier introduces distortion and yields higher frequencies.

† *Sc. Abs.* A, 101, 1915.

* The equation to a damped sine wave is of the form $i = e^{-at} \sin \omega t$. This is equivalent to the Fourier integral $i = \frac{a}{\pi} \int_{-\infty}^{\infty} \frac{\sin(\omega + x)t dx}{a^2 + x^2}$ where a must not be zero. See also EXPERIMENTAL WIRELESS, p. 292, February; p. 397, April, 1924.

resistance, assumed constant, and L the inductance to be regarded as constant and located wholly at the loading coil.

Consider the case of a steady train of electric waves of *single* frequency to impinge on a tuned aerial of zero ohmic and constant radiation resistance. The current at the base of the aerial will grow according to the above expression (*a*). On the cessation of the electric wave train acting on the aerial, the current dies away in accordance with the formula (*b*). When the steady state is reached, no more energy will be supplied to the aerial system, and electrical equilibrium will therefore accrue. The aerial, in virtue of the current flowing in it, will then radiate energy into space at a mean rate equvalent to that supplieu bv the incoming electric waves.

Since the radiation resistance of an open aerial increases as the square of the frequency (assuming the usual formula to be applicable), the duration of the transient epochs—that is to say, the periods of time during which the numerical value of the current is of practical importance—decreases with increase in frequency, *i.e.*, decrease in wave-length. With an aerial of 10,000 metres wave-length* possessing resistance solely due to radiation, the time taken for the current to reach, say, 95 per cent. of its steady value would be considerable, whereas with a 100-metre aerial the time would be comparatively inappreciable. Some idea of the relative times of current growth will be gained when it is stated that the radiation resistance of the short-wave aerial of ***equal effective height*** is 10,000 times that of the long-wave aerial.

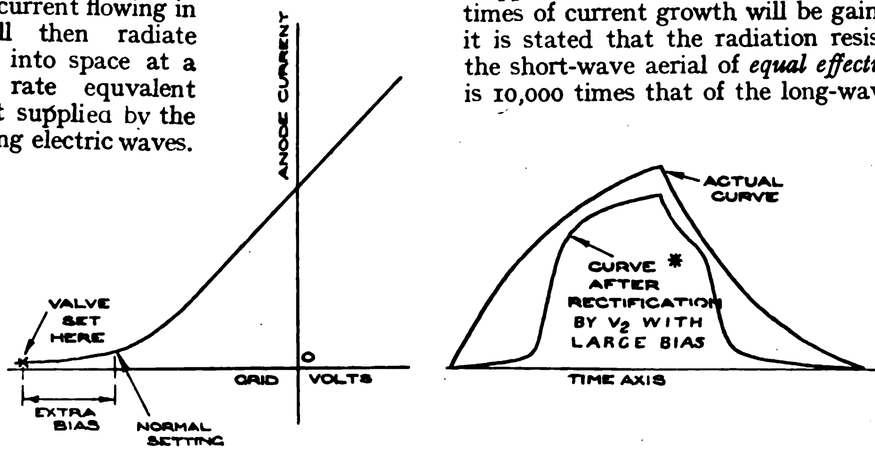


Fig. 2—Diagram showing the "shaping" due to a rectifying valve with a large negative grid bias. The record obtained from an instrument of the magnetic drum class (see Journal I.E.E., August, 1923, also "Experimental Wireless," April, 1924), is of the form shown in Fig. 1a.

In this respect it should be noted that the aerial receives energy from one direction only, but it is capable of radiating energy in many directions. The relative radiating propensity in any particular direction depends upon the *solid* polar diagram of the aerial. For example, the *horizontal* radiation from a frame aerial resembles the familiar figure eight. If we assume the aerial to be vertical and the voltage gradient to be vertical also, it is possible to suggest an approximate thermal analogy. This takes the form of a cylinder of metal placed coaxially in a cylindrical chamber, one half of whose curved surface is at a higher temperature than the other. Energy is absorbed by the central cylinder from the first half of the chamber and radiated to the second half of the chamber.

In practice, of course, the latter is the higher aerial of the two, so that the preceding figure will then probably be of the order of 500 to 1,000. The value of L must, of course, be much greater for the long-wave aerial, and hence for aerials of zero ohmic resistance the ratio of the time constants, *viz.*, $\frac{\alpha \text{ for } 100 \text{ metres}}{\alpha \text{ for } 10{,}000 \text{ metres}}$ will generally exceed 10,000. We conclude, therefore, that the response of a long-wave aerial of zero ohmic resistance to variations in the intensity of electric waves will be severely sluggish, whereas that of a short-wave aerial will be particularly prompt in comparison. The requisite degree of response is a question of

* The aerial is assumed to be associated with a loading inductance.

conditions. In modern radio-telephony it is imperative, in order to secure minimum distortion of the signal, that the aerial should respond rapidly to the variations in the electric field of the incoming waves. Moreover, in this respect ohmic resistance is sometimes a blessing in disguise.

Having broached the subject of telephony, we may digress for a few moments to examine the effect of variation in radiation resistance on very long-wave telephony. Suppose the length of the carrier wave to be 30,000 metres, *i.e.*, 10,000 cycles, and let the highest audio-frequency be 8,000. The side frequencies—with which everyone is now so familiar—concomitant with symmetrical modulation of the carrier wave by choke control, will range from 2,000 to 10,000 and 10,000 to 18,000 cycles. (This is, of course, only a hypothetical case, so that it is unnecessary to consider how many receiving stations are jammed.) For simplicity assume that the modulation on audio-frequencies from, say, 20 to 8,000 cycles is uniform.* At the receiver—which is taken to be distortionless—the modulation will depend upon the radio-frequencies of the side waves. This can be explained in the following way. The radiation from an aerial varies directly as the square of the frequency, assuming the effective height to be independent of frequency. Thus the energy radiated by the two radio-frequencies of 8,000 and 12,000 (corresponding to an audio-frequency of 2,000) will be proportional to $8^2=64$ and $12^2=144$ respectively (total 208). The corresponding figures for an audio-frequency of 4,000 are 36 and 196 (total 232), and those for 10,000 are 0 and 400 (total 400). Hence the total energy radiated by both side frequencies increases with the audio-frequency. Also it should be observed that for any given modulating audio-frequency the energy radiated is greater for the upper than for the lower side frequency. At an audio-frequency of 10,000 there is zero radiation from the lower side band, because the aerial current never changes. In Fig. 3 is portrayed a curve showing the energy radiated at various frequencies, using the elementary hypothesis stated above. If one of the side bands is to be suppressed, clearly on an energy basis the lower one would be chosen, since the radiation from the upper is much the greater of the two. At the receiver, which is assumed to receive all frequencies in the band from 2,000 to 18,000 cycles equally well, there would be perceptible distortion, owing to the accentuation of the higher tones. If the upper band were suppressed and the lower band retained, the lower tones would be accentuated.* The foregoing discussion is based on currents of different audio-frequencies from 20 to 8,000 cycles after the steady state has been attained. It is quite independent of the dead-loss ohmic resistance of the aerial—which may, therefore, have any finite value—since we assumed all the side frequencies in the aerial circuit to be of equal amplitude. When we penetrate the realms of practical radio there are numerous obstacles to be encountered in long-wave telephony, but these are beyond our present purpose. The object of our remarks was merely to illustrate in a somewhat exaggerated manner the eccentricities of appreciable variations in the radiation resistance of a radio telephonic transmitting aerial.

Having dealt with aerials of zero ohmic but actual radiation resistance, we are tempted to inquire what happens when the radiation as well as the ohmic resistance is evanescent. The aerial circuit then possesses capacity, but no resistance. It would appear that in the event of a steady train of electric waves falling on the aerial, the current would grow without cessation, the system *thus continuously absorbing but never radiating energy.* This is directly opposed to a proper physical conception concerning the phenomena of absorption and radiation of electro-magnetic energy. It is known from experiments on heat that a good thermal absorber (a dull black kettle) is also efficient as a thermal radiator, whereas an inferior absorber (a highly polished silver kettle) is a poor radiator. Moreover, an aerial of zero radiation resistance would be incapable of abstracting energy from electric space waves. The citation of a concrete example may make the

* The steady state is now being discussed.

* A flat tuning curve from 2,000 to 18,000 cycles is, of course, out of the question in practice, but as we have stated already, the illustration is purely hypothetical. Also the attenuation of the waves travelling through space depends upon the frequency, so that the curve of Fig. 3 as applied to a receiver necessitates equal attenuation for all frequencies.

matter clearer still. Suppose an inductionless coil of thin insulated wire is formed by doubling the wire back on itself and then winding it closely on a circular ebonite cylinder. The coil will have zero radiation resistance and an electro-magnetic field will not induce a current therein.* Thus the property of radiation imbues electrical circuits with something approximately analogous to a safety valve, inasmuch that it prevents the current from running riot and attaining an extremely large value.

Generally speaking, it is impracticable to test even approximately the validity of the foregoing analysis pertaining to aerials of zero ohmic resistance, by resorting to elaborate experiments at temperatures in the neighbourhood of absolute zero. Until some enterprising metallurgist presents us with a metal, pure or alloyed, having superconductivity at ordinary temperatures, the only suitable weapon at our disposal is the thermionic valve with its reactive propensities. For example, using controlled reaction on a wave-length of 12,000 metres, it is possible to adjust the decrement of the circuit to such a low value that a fairly strong impulse, *e.g.*, an atmospheric, is audible for five seconds or more after the impulse itself has subsided. A suitable succession of impulses reminds one of a bell being tolled. The depth of tone can be varied by altering the beat-note due to the local oscillation generator.

During the reception of electro-magnetic energy by an aerial, there are two actions which may be discussed. (1) Energy is dissipated in heat due to ohmic resistance, resulting from eddy currents in the aerial and in the ground, leakage to earth and dielectric loss. The total energy lost up to any time t can be represented by

$$\int_0^t i^2 r\,dt$$

where i is the current at the base of the aerial at any instant, and r is the resistance responsible for the occurrence of loss. The power or rate of energy loss at any instant is i^2r. (2) Energy is radiated into space from the aerial due to the oscillatory current which flows in it. This can be represented up to any time t by

$$\int^t i^2 r_a dt,$$

where r_a is the radiation resistance. The power loss is at a rate equal to t^2r_a. It should be observed that the value of r_a is referred to the current at the base of the aerial. If the current at some point above the loading coil were chosen, the value of r_a would, according to this way of viewing the matter, be greater than that when i is taken at the base of the aerial. Moreover, the radiation resistance of the aerial is really a mean value obtained from all the i^2r_a components on the aerial.

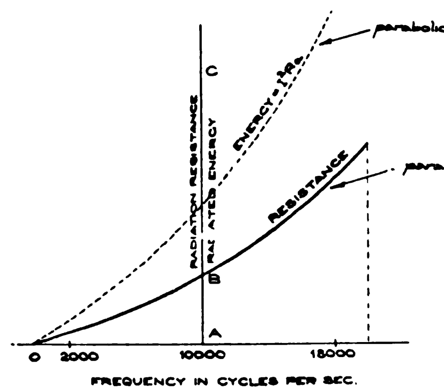


Fig. 8—Diagram showing radiation resistance and radiated energy for transmitting aerial. The amplitude of the current is assumed to be the same for all frequencies, also the usual formula for the radiation resistance of an open aerial is assumed valid.

When a steady train of waves arrives, the aerial current builds up until the energy dissipated in heat is equal to the *net* amount supplied from the waves. Energy is also radiated at the frequency of the waves at a steady rate equal to i^2r_a. Absorption from the electric waves occurs at an equal rate, in addition to that dissipated in heat. When there is no dead loss, the energy absorbed is equal to that radiated, so that in the analytical sense the net transfer of energy is zero. A rough comparison can be made between the aerial and a direct-current motor.* The rotation of the armature causes a back E.M.F. When the impressed and back E.M.F.'s are equal the efficiency of the machine is 100 per cent. Now the current

* In practice, of course, the coefficient of coupling between the go and return paths of the wire would not be quite unity, owing to the thickness of the wire and insulation. The illustration is adequate for the purpose in view, in spite of this slight defect.

in the aerial can, for the sake of rough analogy, be regarded as creating an E.M.F. which opposes that due to the electric waves. The smaller the difference between the two the less the energy dissipated in heat. Equality of the E.M.F.'s is attained when the dead loss is zero and the energy absorbed is identical in value with that radiated.

Coming now to the application of reaction to reduce the resistance of an aerial, we are apt to ask if one or both of the aerial resistances (ohmic and radiation) are reduced. It is well to remember that the latter has more of a mathematical than a physical significance, being a useful artifice to facilitate calculation. Radiation is an inherent property of any inductive circuit—in general all electric circuits possess inductive and radiative properties, accidental or otherwise—whilst dead loss due to ohmic resistance is an inherent defect, which is capable of rectification up to a point by the aid of reaction. It is usually accepted that reaction is mathematically equivalent to a reduction in the high-frequency resistance of a circuit. The result is simply that the energy dissipated in a resistance whose value is equal to that compensated by the valve, is diverted from the anode battery by the valve acting as a timing device which controls the amount and phase of the supply. It must not be inferred that the energy tapped from the anode battery has the same physical significance as an increase in the intensity of the electric waves which would, in the absence of reaction, yield an aerial current of like magnitude. The employment of reaction is accompanied by a decrease in the decrement of the circuit, as well as by the aforesaid action of the anode battery. Starting with a definite degree of reaction, the aerial current due to a steady train of waves has a corresponding value. As the reaction is augmented, the current rises until it attains the same value as that in an aerial of zero dead loss—provided, of course, the reaction can be controlled adequately up to this point. Reaction beyond this stage entails radiation (in addition to that equal to the amount absorbed from the incoming waves) into space; in fact, the aerial acts as a transmitter. Generally it will be found that the set bursts into oscillation before the zero dead-loss stage is reached.

Summary.

The cardinal features in this article can be summarised thus:—

(1) The effect of a very low resistance aerial* circuit—that is, one in which the value L/R is relatively large—is to distort an incoming morse signal of square formation to one which is rounded. If the envelope of the telegraphic signal is sufficiently rounded after rectification it is aurally incomprehensible. In radio-telephony the higher acoustic tones are attenuated appreciably.

(2) The current in an aerial of zero ohmic resistance is finite in value. In growth and decay it follows approximately the usual exponential-sinusoidal law, the damping factor being $r_a/2L$, where r_a is the radiation resistance arising from the radiation of energy into space, which occurs whenever a current flows in the aerial.

(3) A short-wave aerial of zero ohmic resistance is more responsive than a long-wave aerial of zero ohmic resistance, since the damping factor ($r_a/2L$) of the former is many times that of of the latter owing (*a*) to larger radiation resistance; (*b*) smaller inductance.

(4) An electric circuit of zero radiation resistance can neither absorb nor radiate electro-magnetic energy. (Neither heat nor light waves are included here.)

* An open aerial is implied unless otherwise stated.

Telephony and C.W. Transmitters for 100 Metres.

By G. E. MINVALLA, A.C.G.I. (6BN).

To those amateurs interested in long distance C.W. telegraphic communication, the following article should be of great interest. Useful information is given with regard to the elimination of losses which are so likely to occur at very high frequencies.

IT is clear to all students of wireless engineering that the present tendency to reduce the wave-length of long-range transmitters has by no means reached finality. It is therefore appropriate to recapitulate a few points in the design of such transmitters, since these points have often been overlooked in the construction of transmitters for longer wave-lengths.

The first point to which attention may be drawn is the use or presence of iron in any part of the transmitter. It is common practice in long-wave commercial stations to mount the transmitter on insulating panels, carried on an iron frame-work. Now the eddy-current losses in iron for low frequencies can be found from the expression :—

$$W_E = K\, t^2 f^2 B^2 v.$$

Where W_E = loss.
K = constant depending on the grade of iron.
t = thickness.
f = frequency.
B = flux-density.
v = volume of iron used.

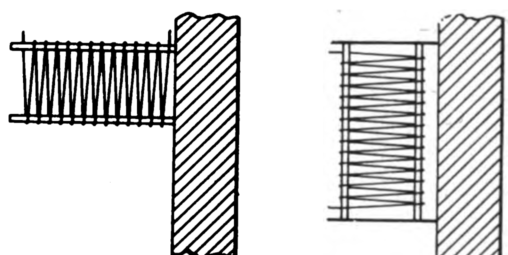
While this expression is not strictly accurate for very high frequencies, it is nevertheless a sufficiently close approximation to show the enormously increased losses at high frequencies, as compared with commercial frequencies.

The next point with regard to iron is the hysteresis loss. This can be expressed by $W_H = HvfB^{1.7}$, where H is a small constant. This has been found to be accurate over a wide range of frequencies, and may therefore be regarded as substantially correct for radio work.

To summarise, then :—The total losses in iron may be expressed as $W_E + W_H = Af^2 + Cf$, where A and C are constants for any particular framework.

Considering a frame of ordinary iron comprising 1,000 c.c., 2·5 mm. thick, and carrying an effective flux-density of 100 lines per sq. cm., these constants come out to approximately $10^{-5} f^2 + 5 \cdot 10^{-4} f$.

Now when f is 30,000 cycles and the input power 10 k.w., the loss is negligible. But,



(a) (b)

Fig. 1.—(a) This method of mounting a transmitting inductance near a wall is liable to introduce losses, while (b), with the magnetic axis of the coil parallel to the wall, is more efficient.

if the input power is 10 watts and f is three million cycles the state of affairs is very different.

It may easily happen that 90 per cent. of the energy supplied is wasted in the iron framework.

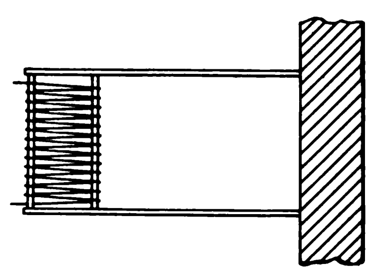


Fig. 2.—A still more efficient arrangement which embodies the advantages of the Fig. 1 (b) method and at the same time reduces the eddy current losses, etc., to a very small value.

The remedy for this is obvious. Iron must be avoided at all costs. If a non-

magnetic metal such as brass is used, the hysteresis losses will for all practical purposes disappear. The eddy-current losses will be reduced, as the flux-density will be lower, but they will still exist, and may be important. Hence it is well to avoid any metal in the framework of the transmitter. Hard dry wood is quite as good mechanically, is easier to work, and is incomparably better electrically.

The transmitter having been assembled in a wooden frame, the next point is its position in the room. Walls (especially outside walls) are usually slightly damp. They therefore conduct. In consequence eddies will be induced in them and energy wasted, if the magnetic lines of force are allowed to cut them.

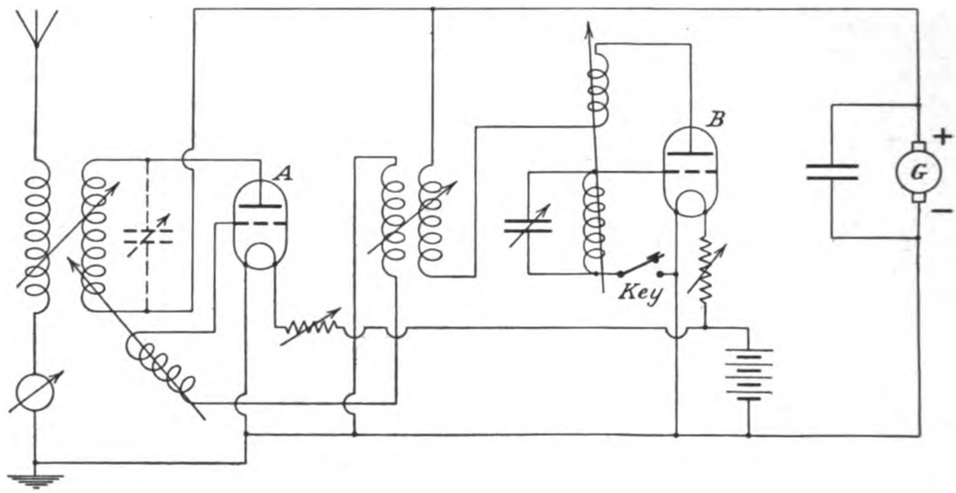


Fig. 3.—A short-wave C.W. circuit wherein a master valve is used to drive the main power system.

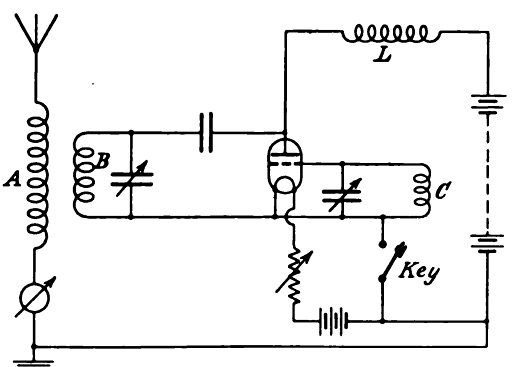


Fig. 4.—This circuit embodies the desirable properties of loosely coupling a closed circuit to the A.T.I. which tends to keep the frequency of the oscillations constant.

Hence the transmitter should be installed so that the magnetic axes of any coils carrying H.F. currents are parallel to the nearest wall and as far from it as possible. This is illustrated in Figs. 1 and 2.

If an aerial current of ·2*a* (input ten watts) is obtained with the A.T.I. as in Fig. 1 it is probable that moving the latter to the position shown in Fig. 2 will double the aerial current!

The A.T.I., closed circuit inductance, and grid coils, may well be wound with copper strip. No appreciable advantage will be derived from the use of litzendraht.

Next, as to the circuit to be employed. The writer is strongly in favour of the "independent drive" circuit, as it is of the utmost importance that the wave-length should remain constant. The principles of this circuit are shown in Fig. 3.

The valve B is arranged as an oscillator by coupling its grid and plate together. A coupling coil is connected in series with either the grid or the plate coil, and is coupled to the grid of the valve A. The grid and plate of valve A are coupled together in such a manner as to suppress oscillation, and the valve acts merely as a high-frequency power amplifier. If necessary the grid is biassed so that it works on the straight part of its characteristic; the alternating grid voltage applied by the oscillator valve thus produces currents of the same frequency in the plate circuit, and hence the radiated wave is entirely independent of the aerial constants.

Modulation is obtained by coupling a control valve to the aerial circuit.

When once set up, this circuit is quite straightforward and is capable of giving exceptionally long ranges owing to the facts that (1) The wave-length is absolutely constant, and (2) both valves are working at maximum efficiency. For telephony, a further advantage is that the carrier wave is perfectly sinusoidal, and if the same is true of the receiver heterodyne no distortion will result.

Fig. 4 shows a very simple transmitter for low power work which nevertheless gives quite good results.

It has not the same advantages as the circuit shown in Fig. 3, but it is cheap to assemble and simple to handle. The coils A and B may be tightly coupled together, no coupling at all being required with C.

The valve oscillates, of course, through its own natural capacity. A further simplification may be obtained by eliminating the closed circuit of B, but the writer does not recommend this.

L is, of course, a high frequency choke coil, and may well be wound in the "frame-aerial" fashion which came into prominence some months ago.

In conclusion, the reader is reminded that the frequency to be dealt with is exceedingly high, and in consequence stray capacities must be avoided like the plague. The valve capacities must be utilised if possible, otherwise cut down to a minimum by careful spacing of the leads.

No more metal than is essential should be used anywhere. In this connection it is of interest to remember that the quantity of metal in a condenser may be reduced by closer spacing of the plates, or by introducing mica between them, the capacity remaining constant.

Telephony Reception.

By H. J. NEILL.

The ideals to be aimed at with a view to the most faithful reproduction of broadcast telephony are given in the following article. For those desirous of obtaining perfect loud-speaker reception, the information on resistance-coupled amplifiers should be of interest.

THE object of these notes is to set forth some of the main considerations in obtaining a good and faithful reproduction in telephony.

It seems that the transmissions of speech and music from the B.B.C. stations are very satisfactory, and yet the number of equally satisfactory receptions of the broadcast concerts seems to be few. This is probably due to the fact that most experimenters blame their loud speaker and not the receiving system, whereas in many cases the receiver itself is mainly to blame.

For the reproduction of speech it is sufficient if all frequencies from about 500 to 5,000 cycles per second are satisfactorily amplified and reproduced. Although the same frequency band will permit of some sort of musical reproduction, much of the quality is necessarily lost.

It is not excessively difficult to design a wireless receiver and amplifier which will deal with a much wider band of frequencies than this. If, however, such a design is attempted making use of iron-cored coupling transformers for audio-frequency amplification, almost insuperable difficulties are met. If either the resistance or reactance-capacity methods of coupling are used the problem becomes easier.

The resistance coupling provides the easier design and will therefore be considered. The extra H.T. supply required does not appear to be a drawback because a high value is necessary for any valve suitable for the operation of a loud speaker.

It is not the intention to discuss loud speakers themselves nor yet to discuss any part of the wireless receiver except the detector and low-frequency amplifier. It

may be helpful, therefore, to work out the main points in a design for a receiver to work say three miles from a B.B.C. main station with a good aerial. If conditions are other than these, high-frequency amplification must be resorted to. For simplicity the set will be loose coupled to the aerial, and the design of the aerial circuit will not be considered.

In order to get a good "detected" signal strength a valve detector is probably best. The effect in the anode circuit of a valve depends only upon the voltage applied to the grid and not upon the current or energy in the grid circuit. Now, assuming the energy available constant, the voltage across the grid and filament of the valve is inversely proportional to the capacity in the closed circuit. Therefore that capacity should be kept as small as possible. The capacity of the valve and connections is generally of the order of 25-30 $\mu\mu$F. In order to get a respectably wide tuning band a condenser of five times this value is sufficiently large, say 0.00015 μF. A square law condenser is a great advantage and should be shielded. The closed circuit inductance must be designed so as to tune to the required wave-length with about 0.00005 μF capacity in shunt, and should be of an efficient form, say No. 20 S.W.G. wire wound in a hexagonal frame 6" across and spaced about 10 or 12 turns per inch. This, of course, means a large coil, but it is worth it. As an example, at three miles from 2LO with Igranic plug-in coils only 2 volts could be obtained on the grid of the detector valve, while with carefully-made coils of the above type 5.5 volts was obtained without the use of reaction.

Method of Rectification.

The question of the detector next arises. There are several methods of using a valve as a detector, the best known of which is that using a leaky grid condenser. This method is admirable if signals are weak, say under 1 volt, and the circuits are properly designed. If, however, signals are strong, the grid leak does not work so well, and the use of the lower bend of the anode-current/grid-volts curve appears more effective. The latter method is, of course, not so effective if signals are weak. It has, however, one great advantage, and that is that no grid current need flow. A negative grid-bias, of which the value will be determined later, should be used.

The next step is to decide on the valve to be used as a detector, bearing in mind that it is to be resistance-coupled to the next valve. The valve should exhibit a sharp lower bend on the anode-current/grid-volts curve and have a high voltage amplifying factor. Certain valves sold as detectors have a magnification factor of only about two or three, and an anode impedance of a very low value, and while these are excellent in some arrangements they are useless for the purpose of resistance-coupling to a subsequent valve. An R valve is suitable, and the writer has found the Phillips E valve very good indeed, both as a detector and amplifier.

The Anode Resistance.

The anode resistance next claims attention. The alternating voltage on the anode is :—

$$\frac{\mu \mathrm{VgR}}{\mathrm{R}+\mathrm{Ra}}$$

where μ=voltage magnification factor of valve
Ra=Anode impedance of valve
R =Added resistance in anode circuit
Vg=Alternating P.D. applied to grid/filament.

It is desirable, therefore, to make R as high as convenient compared to Ra. A value of three times Ra is very suitable. Then

$$\mathrm{Va}=\tfrac{3}{4}\mu \mathrm{Vg}$$

i.e., the amplification is $\frac{3}{4}$ of the maximum possible. A higher value of R would be better, if sufficient H.T. were available. This valve however, is to work as a detector, and so the H.T. and grid bias must be so adjusted that when no signal is arriving the anode-current is practically nothing. The adjustment is best carried out practically by means of a good milliameter temporarily connected in the anode circuit of the valve. The calculation of the values is somewhat clumsy. Actually it is best to make the grid so much negative that no grid current can pass with any signal likely to be received, if necessary, increasing the H.T. voltage. In a particular case of a Phillips E valve the grid was fixed at -12 volts with respect to the negative end of the filament ; the anode resistance

was 150,000 ohms, and the H.T. supply was 120 volts exactly.

It may be desirable to use some reaction, and in any case it is not desirable further to amplify the radio frequency impulses which will be present in the anode of the detector valve. A by-pass condenser is necessary, connected from the anode end of the anode-resistance either directly to the filament or to the H.T. positive terminal. It is frequently stated that the value of this condenser is immaterial and may be 0.001 or 0.002 μF.

The impedance of a condenser is inversely proportional to the frequency of the E.M.F. across it, and at the higher audible frequencies, say at 10,000 cycles per second, a 0.001 condenser has impedance of only about 15,900 ohms. This low impedance is shunting the anode resistance, and hence the frequencies of the higher order will be only feebly amplified or even not amplified at all. Now, it is our desire to amplify all frequencies in the audible range equally, so the impedance of the by-pass condenser must be much higher than the anode resistance, so that its shunting effect is negligible at all times. This condenser, however, must be large enough to by-pass effectively the radio frequency impulses. It is easy to select a suitable condenser by the aid of the formula

$$Z_f = \frac{10^6}{2\pi f C}$$

where Z_f=impedance at f ∽
f=frequency
C=capacity in μF.

For example, a condenser of 0.00005 μF has an impedance at 16,000∽ of about 199,000 ohms at 300,000∽ (1,000 metres wave-length) of about 10,600 ohms, and at a million cycles (300 metres) of 3,180 ohms. This would be a suitable value for a set to receive wave-lengths from the shortest waves up to about 1,000 metres. The shunting effect on audio-frequency currents is practically nil, while the amplification of radio-frequency currents is reduced to something very small. If longer wave-lengths are to be received a compromise must be effected by reducing the anode resistance while slightly increasing the by-pass capacity.

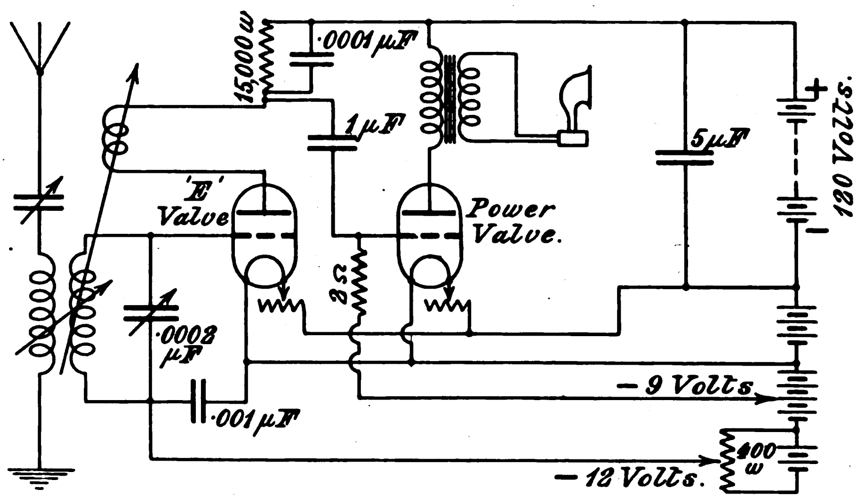


Fig. 1.—A Two-valve Resistance-coupled Amplifier.

If it is desired to use reaction, a suitable coil may be connected between the anode of the detector and the junction of the anode resistance and by-pass condenser. Reaction must, however, be used to a very small degree.

Value of Coupling Condenser.

The next consideration is the size of the coupling or grid condenser, and the size of the grid leak resistance of the next valve. It is assumed that a hard valve is to be used

in the next stage, and that all grid current is to be eliminated by appropriate grid bias, probably about 9 volts if signals are really strong. If grid current is absent the leak resistance may be made high, say one or more megohms. It must be remembered, however, that the grid leak is shunting the anode resistance of the first valve as far as alternating currents are concerned, and therefore it must not be reduced to equality therewith. A value of 2 megohms is very suitable.

The coupling condenser must be sufficiently large to offer negligible impedance to currents of the lowest frequency to be amplified, say 16 cycles. A one μF condenser offers an impedance of 10,000 ohms at 16 cycles, and this value is low compared with other values in the circuit. This coupling has a long time constant, which means that the amplifier takes some seconds to stabilise after switching on and adjusting. This may be a defect, but can only be overcome by decreasing the grid leak resistance or the size of the coupling condenser, or both, all of which it is undesirable to do. Although such an amplifier may get the "staggers" occasionally when being adjusted the good results obtainable are worth a little trouble in tuning.

If the signals are really strong the second valve may be the last, and in this case must be a valve suitable for the operation of a loud speaker. This valve should have a low anode impedance and be capable of large emission from the cathode. The grid potential is determined by the strength of signal expected, and must exceed the peak value of signal voltage. A value of 9 volts has been found suitable when using the previously described detector arrangement at a distance of three miles from 2LO, with a moderately good aerial. The H.T. voltage applied to the anode of this valve must be adjusted so that the tube is operated about the centre of the straight portion of its anode current/grid volts characteristic. If more than one power valve is available a tube should be selected which shows a flat characteristic surface surrounding the operating point.

The loud speaker, if of a high resistance type, may be connected directly in the anode circuit of the last valve. It is generally preferable, however, to use a transformer and low-resistance telephone, since then capacity in long leads to the telephone has less effect upon the quality of reproduction and also the risk of injury to the instrument is less. It is not proposed to deal with the design of an output transformer, but mention may be made of one or two points.

An open core is to be preferred of very generous sectional area and not too long. The primary winding should be wound in sections or in some form to reduce its self capacity as far as possible, and should be of generous gauge of wire. Resistance does not help. Inductance is required. The same remarks apply to the secondary or output winding. The turn ratio should be chosen to match the impedances of the two circuits which the transformer is to couple. It is worth noting that the resistance of a loud speaker is practically no guide to its impedance. The makers should be consulted as to the value of impedance. If the valve and telephone impedances are properly matched at about 1,000 cycles, the results are satisfactory.

Additional Amplification.

There are occasions when the above-suggested two-valve arrangement does not give sufficient volume, and a further stage of amplification is required. In this case the power valve should be replaced by an amplifying valve, an R valve being suitable, although special valves with a high value of μ are obtainable. A power valve for resistance-coupled amplification is unnecessary.

The anode of the amplifying valve should be connected to a suitable value of H.T. through an anode resistance. The anode resistance, coupling condenser and grid leak for coupling and amplifying valve to the next in sequence are determined in the same manner as previously set forth. The amplifying valve and anode resistance and H.T. voltage must be chosen so that the valve shall operate about a point in the centre of a plane portion of the characteristic surface. The grid potential is already fixed by the signal strength.

When the three valves are used the last or power valve requires further consideration. The signal voltage applied to its grid will be large. If the peak voltage delivered by the detector is 6 and the voltage magnification

of the intermediate stage is 8 (both of which figures are very easily exceeded) the voltage applied to the grid of the power valve will be 48. This necessitates a grid bias on the last valve of at least 50 volts. Hence the anode potential requisite for most tubes suitable for dealing with this grid voltage and working a loud speaker will be of the order of 500 to 1,000 volts. Of course, the volume obtainable by such an arrangement is immense. It may be mentioned that on a 3-valve receiver similar to that described above a peak voltage of 64 volts upon the grid of the power valve was recorded on signals from 2LO.

In order to control the volume of the 3-valve arrangement the anode resistance of the amplifying valve may consist of a number of small resistances in series. Connections from the junctions of these may be brought to a multi-point switch and the switch arm connected to the coupling condenser so that only a portion of the total potential charge upon the anode resistance is applied to the grid of the power valve. A nice adjustment of volume can thus be obtained, without upsetting the amplifier. Volume must not be controlled by dimming filaments or lowering the H.T. supplies of the amplifying and detecting tubes. With less volume the grid bias and anode potential of the power valve may be lowered if the characteristics of the tube permit.

In conclusion, the author has had a 2-valve receiver designed on the above lines in operation for some time at about a distance of three miles from 2LO. This set has at all times given ample volume for a high room 19 ft. by 17 ft., and a satisfactory reproduction. On several occasionsthree valves were used. The last valve was a special valve, and the anode potential was 600 volts and grid bias 70 volts. Signals were clearly audible 500 yards from the house. It does not seem, therefore, that, if a 3-valve receiver will give this volume with resistance-coupling the use of transformer coupling is advantageous. True, transformers give a greater amplification per stage, but resistance coupling seems to provide all the amplification which is required. Choke-capacity coupling is quite satisfactory, but the chokes are not so easy to design, since their impedance at the lowest frequencies to be amplified must be very high, and this requirement is apt to lead to excessive self-capacity which reduces the amplification of the higher frequencies and which may also lead to resonance of the choke at certain frequencies.

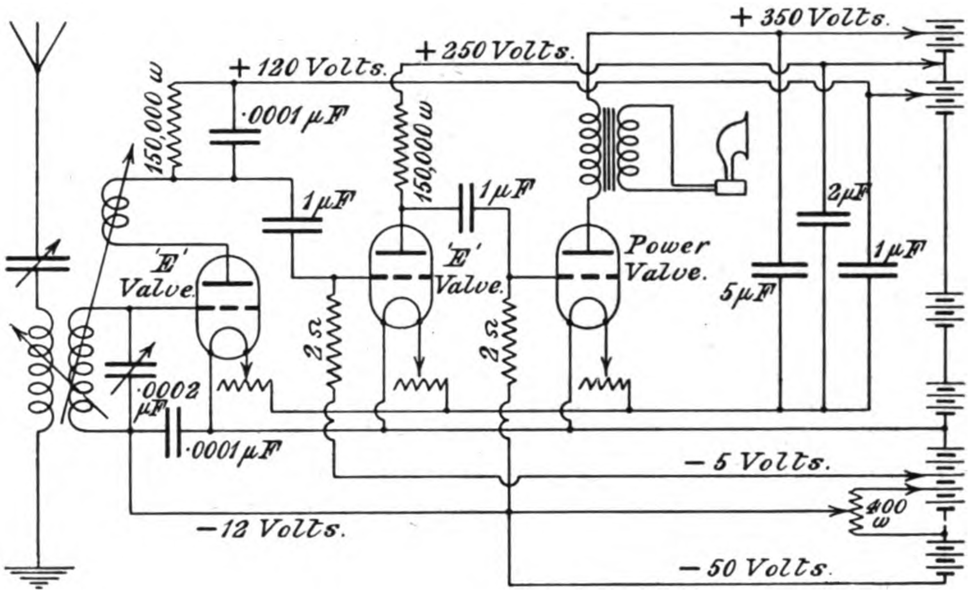


Fig. 2.—A Three-valve Resistance-coupled Amplifier giving Values of the Components.

Some Applications of the Thermionic Electric Triode to Purposes other than Radio Communication.

By H. A. THOMAS, M.Sc.

The amateur experimenter is sometimes handicapped by lack of suitable measuring instruments, though, as here shown, a valve can often be made to take their place. The author describes below numerous applications of the thermionic triode for electrical measurements.

THE thermionic three-electrode valve has undoubtedly opened the gate to a new branch of science, since it has made possible the measurement of very small electrical quantities. It is by virtue of these properties that the technique of radio communication has been suddenly elevated to a position that stands without parallel as far as delicacy and precision is concerned.

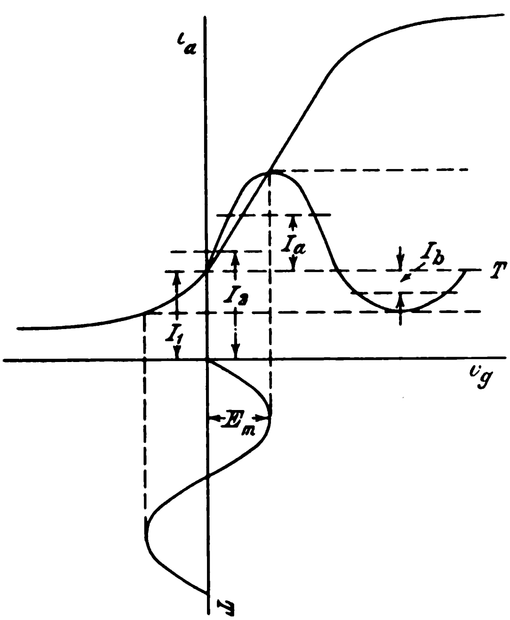


Fig. 1.

It has been the author's policy for several years to exploit the unlimited applications of the valve to general physical science and engineering, and I venture to set down a few of the most important results that have been obtained, results which I hope will demonstrate that the scope of the instrument is not limited solely to radio communication.

The Measurement of Small A.C. Voltages.

It is always a difficult problem to measure a potential difference without absorbing power, and in the case of an alternating P.D. it is theoretically impossible. Yet, we can in practice limit the power taken by the measuring instrument to an exceedingly small amount. The most effective method is to use an electrostatic voltmeter, since the power taken can only be that due to the constants of the medium between the two vanes of the instrument which virtually form a very small condenser. The forces of attraction which are utilised to operate such an instrument are exceedingly small, especially when the capacity must be reduced to a minimum so as not to modify seriously the circuit across which the instrument is connected.

This soon becomes the limiting factor in the sensitivity of electrostatic meters, and it is exceedingly difficult to build an instrument which will read less than 1 volt.

However, it is possible by means of the valve to convert a small A.C. voltage change into a D.C. change which will affect a delicate galvanometer. It is well known that the application of an alternating potential wave to the grid of a valve produces a change in the direct anode current, and we will now consider the theory of this phenomena in detail.

Let Fig. 1 represent the v_g-i_a characteristic curve for any particular filament current and anode potential.

The D.C. anode current will be I_1 if the grid be at zero potential with respect to the negative end of the filament. Now apply a sinusoidal wave of R.M.S. value E to the grid, represented by the amplitude $E_{max.} = \sqrt{2}E$, and the vertical time scale. The corresponding anode current curve will be represented on the horizontal time scale as shown, where T is the periodic time and equals $1/f$, where f is the frequency of the applied wave.

The new mean anode current I_2 will now be the mean between the means of both halves of the waves Ia and Ib plus the original current I_1.

The complete circuit diagram would be as in Fig. 2.

E = Unknown H.F. E.M.F. to be measured.
I_1 and R_2 are known
or V_1, R_1, and R_2 are known.

In practice this is a very delicate method of measuring small A.C. voltages.

The power taken is small, and only in exceptional cases does the self capacity of the grid to filament modify the H.F. circuit.

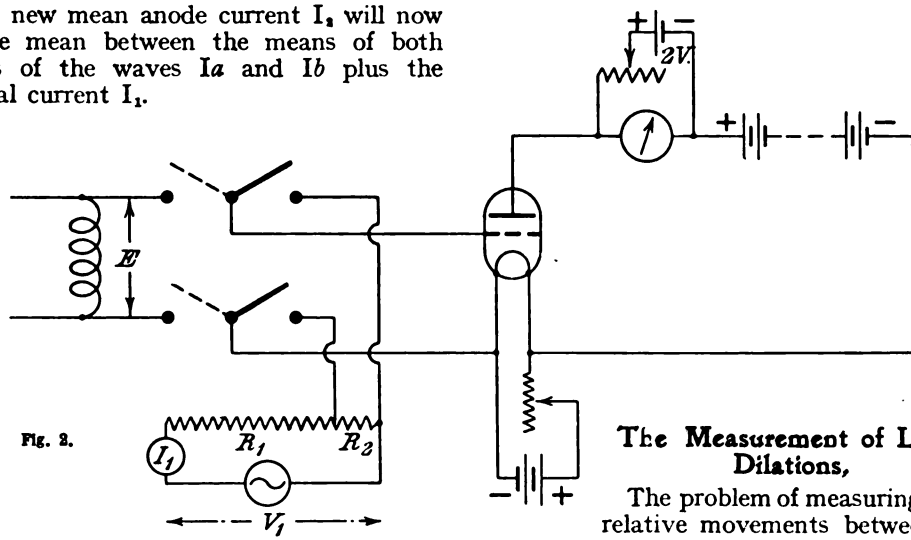


Fig. 2.

If the part of the original characteristic curve under consideration is represented by $i_a = f(v_g)$

we have mean + ve. value $= \int_0^{\frac{T}{2}} f\,(E_{max} \sin \omega t.)$

and mean − ve. value $= \int_{\frac{T}{2}}^{T} f\,(E_{max} \sin. \omega t.)$

giving—

$$I_2 = I_1 + \int_0^{\frac{T}{2}} f(E_{max.} \sin \omega t.) - \int_{\frac{T}{2}}^{T} f\,(E_{max} \sin \omega t.$$

If the damping of the D.C. instrument is high it will give a constant deflection if the applied grid frequency is low and therefore we can calibrate at quite a low frequency from a commercial supply.

The normal anode current can be balanced out, and then the change can be observed on a delicate galvanometer.

The Measurement of Linear Dilations,

The problem of measuring small relative movements between two mechanical members by an apparatus which produces no constraint on the members is one which can only be solved by one of two available methods: (*a*) optically; (*b*) electrically.

The optical method consists of attaching a tiny mirror to the moving body and observing the movement of a beam of light as shown in Fig. 3.

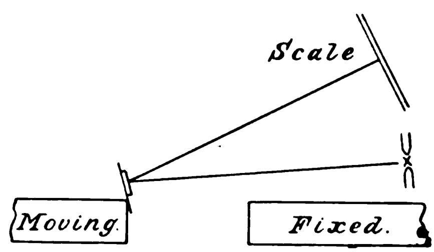


Fig. 3.

This method has very definite limitations, since the mirror cannot be reduced below a certain size.

The electrical methods consist of moving

mechanical members which constitute an electrical circuit, perhaps the most obvious of which is to make the two ends form a condenser, the plates of which will then move and vary the capacity.

This variable capacity can be converted in several ways into a suitable observable change of an electrical quantity, such as a current, which will be proportional to the capacity, if an A.C. voltage be applied in a series circuit.

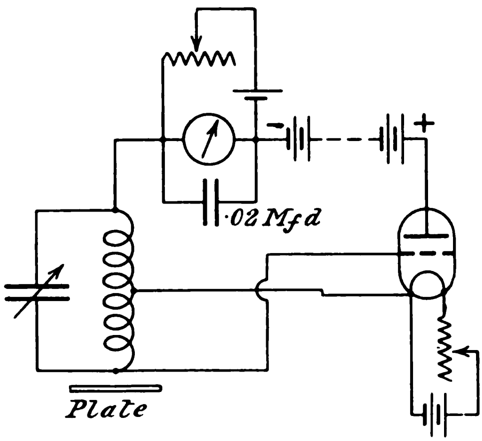


Fig. 4.

However, the author has invented a far more delicate method, which is capable of great precision and sensitivity.

The general arrangement of the apparatus is as shown in Fig. 4, and consists essentially of a Hartley Oscillating Circuit, in which the oscillations are reduced by absorbing energy by means of a local moving plate in which eddy currents are introduced.

Let us consider the vector diagram of such a circuit, Fig. 5.

The E.M.F. current and flux vectors E, I and ϕ respectively for an oscillating circuit will be in phase at resonance, and the flux vector will induce a back E.M.F. E_b in the plate, lagging 90° behind the flux.

The E.M.F. will produce circulating currents in the metal, the magnitude and phase of which will depend on the resistivity and ratio of $\frac{L}{R}$. The inductance L will be a constant depending only on the form of the generating oscillatory coil, and R will vary for different metals, the lagging angle ϕ being a minimum when $\frac{L}{R}$ is a minimum.

This secondary current I_b, with its associated flux ϕ_b will produce a back E.M.F. in the original coil E_2, which in turn will produce its current I_2 still in phase with E_2 since the frequency is that of the original.

The net E.M.F. and current will thus be the vectorial sum of E_1 and E_2 and I_1 and I_2, namely E and I, and we see that the effect of the metallic member is to virtually increase the high frequency resistance of the oscillating coil, and thus to reduce the oscillating grid volts, and as we have seen before, this will mean a D.C. anode current change.

The type of curve obtained for the current plotted against the distance of the plate from the coil is as shown in Fig. 6, and it will be seen that over the range δx the current variations are linear.

If the plate be so adjusted that the current is at about the mean of these two values, any further small relative movement will produce a big change in anode current.

The apparatus has been used as an extensometer by making the coil about ¾" in diameter and moving a 1" steel or lead plate near to it. It is possible to measure one hundredth of a millionth of an inch in this way, the linear part being approximately

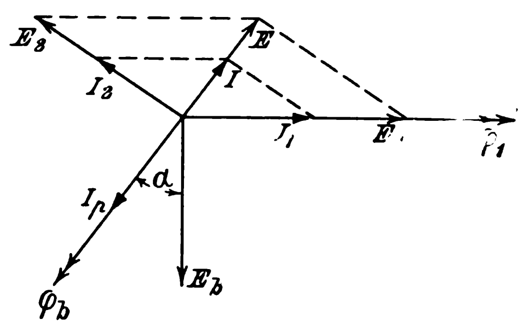


Fig. 5.

over a range of at least one hundredth of an inch.

If the movements are vibratory or pulsating we can photograph them accurately by employing an Einthoven String Galvanometer as our recording instrument. Frequencies up to 600 per second can easily be recorded and the wave form of the mechanical vibration obtained. No attachment is neces-

sary to the moving metal body, as usually it is large enough to act directly as the plate in the electrical circuit.

The method is now being used as an extensometer for vibratory stresses, and can be applied to any problem connected with tortional or longitudinal stresses. The calibration is, of course, performed mechanically by shifting the coil or plate by a definite known amount.

The type of record obtained from a vibrating bar is as shown in Fig. 7, and is marked by times lines of a twenty-fifth of a second by a suitable optical marker incorporated in the galvanometer.

The Measurement of Small Thermal Changes.

If we use a delicate thermo-couple as a means of indicating temperature, we find that there is a lower limit below which no galvanometer will give readable deflections, We can, of course, apply our small E.M.F. to the grid of a valve, and measure the anode current change by means of a balanced galvanometer.

The limits of this method are imposed by the difficulties of maintaining both battery voltages and valve conditions, at which "point creeps" in the anode current are larger than the change to be observed. With a view to extending the possibilities of the triode in this direction, the following method is suggested.

The source of thermal energy is allowed to affect the couple intermittently by means of a shutter similar to a cinematograph shutter, the time during which the couple is affected being considerably larger than the natural lag of the instrument.

If the couple has a lag of 1/100 sec. the shutter would cut out the source 50 times per second.

The E.M.F. wave thus obtained is applied to an audio frequency amplifier and the output, which can be made as large as desired, is measured by a vibration galvanometer. The difficulties of creeps are eliminated, and although the wave applied may be of a peculiar shape, the comparison of sources can be calibrated by means of a known audio source and a potentiometer.

The general arrangement is shown in Fig. 8.

The vibration galvanometer (V.G.) is tuned to the frequency of the interruption of the source, and since this is quite low, the galvanometer can be very robust in construction.

The Measurement of Minute Fluid Pressures.

An apparatus similar to Fig. 4 has been utilised for measuring very small water and air

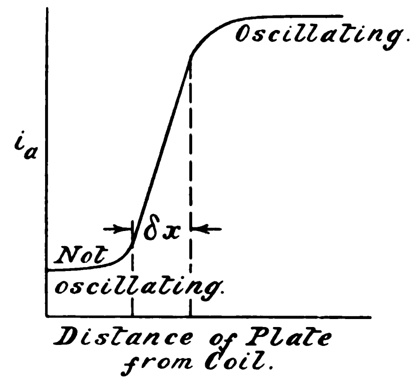


Fig. 6.

pressure changes, by recording the motion of a diaphragm, the one face of which is exposed to the pressure under consideration. No decrement is added to the diaphragm, and since the movement can be very small, the latter can be made so stiff that its natural period is far higher than the pressure changes to be measured. The apparatus is shown diagrammatically in Fig. 9.

The Maintenance of Mechanical Vibrations.

Consider the case of a metallic plate lightly held by a spring, so that it can vibrate axially as shown in Fig. 10.

If the plate move to position 1 the oscillation will increase and the anode current will increase. If it move to position 2 the current will decrease.

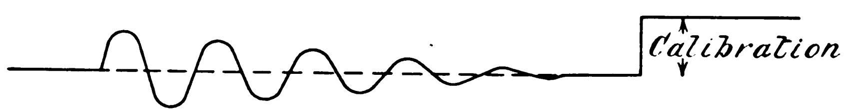


Fig. 7.

Now this changing anode current passes through the high frequency oscillatory coil itself, as well as through the plate and H.T.

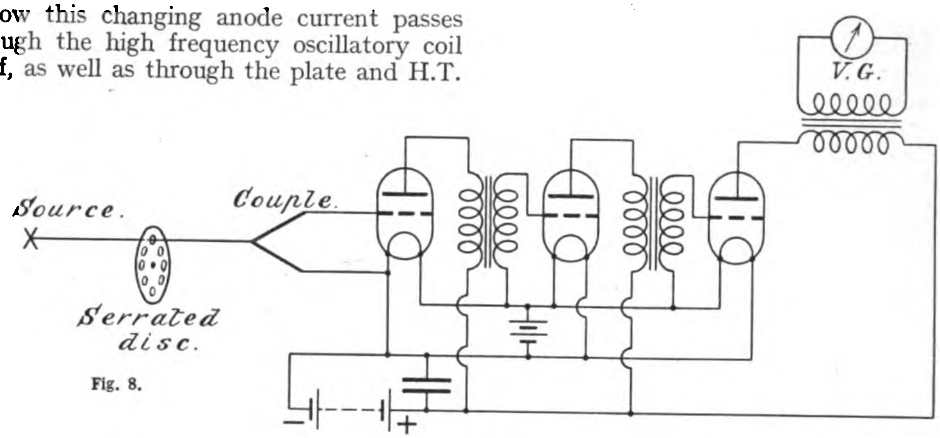


Fig. 8.

battery, and since the coil possesses inductance, there will be a lag between the current and the movement of the plate.

In Fig. 11 if the total periodic time be T we shall have a time of $\frac{T}{4}$, for each quarter movement to and away from the datum to the point of maximum amplitude of vibration.

The mean pull of the magnet during the first quarter period is represented by P_1, which is the area ABGF divided by FG, the mean pull as the fork returns is P_2, which again is area $\frac{BCHG}{GH}$. Similarly the mean pulls for the third and fourth periods will be P_3 and P_4.

Now from this diagram it is evident that the restoring pull in the second period is greater than the pull in the first period, thus assisting the motion, and the assisting pull P_3 in the third period is greater than the pull P_4 during the fourth period, still assisting the vibration.

The displacement of the flux curve due to the inductance of the coil thus maintains the mechanical system, by applying a small amount of power during both half swings.

A lightly damped mechanical system is easily maintained and a tuning fork, especially at low frequencies can be easily operated by this method with one small "R" valve.

The circuit arrangement is shown in Fig. 12.

The advantages of this method over the ordinary type of contact maker are apparent,

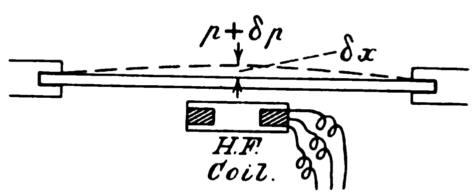


Fig. 9.

the applied pull is not sudden, and the decrement which is added to the vibrating system is negligible; in fact this may become zero under many cases, as is shown in the next section.

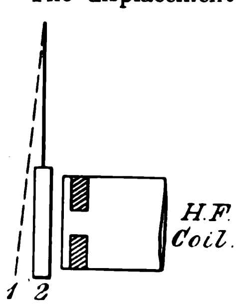


Fig. 10.

The Maintenance of Pendulum Vibrations.

It is possible by a slight modification to utilise this method to sustain a pendulum and operate a clock dial without adding to the natural damping of the mechanical system.

The original suggestion has been published* and the completed clock may be seen in The Royal Society Exhibit in the Govern-

* *Journal of Scientific Instruments*, Vol. 1, No. 1.

ment Pavilion at the British Empire Exhibition at Wembley.

The arrangement is illustrated in Fig. 13.

On the bottom of the pendulum bob a special shoe is fixed, the two surfaces, AB and CD, about 1″ wide, being covered with thin sheet iron.

This shoe swings above the Hartley high frequency oscillating coil, and the changes in the anode current affect the magnet, which operates upon the armature F, affixed to the pendulum. The type of anode current curve is shown in Fig. 14 the current Io being that due to no oscillation. The transition stage is very sudden, and there will be a lag due to two factors, firstly, because the critical resistance of the circuit to start oscillations is not the same as that required to stop them, this resistance being of course dependent upon the position of the eddy plate with respect to the coil, and, secondly, because the inductance possesses a time lag.

Thus the accelerating pull given at the dead centre will be greater than the next de-accelerating pull, thus imparting work to the pendulum.

The work which the pendulum has to perform is to drive its metallic relay shoe through the high frequency magnetic field produced by the oscillating circuit. It can readily be shown that this work will be the same as that of moving the iron through a field of constant magnitude equal to the R.M.S. value of the original alternating field.

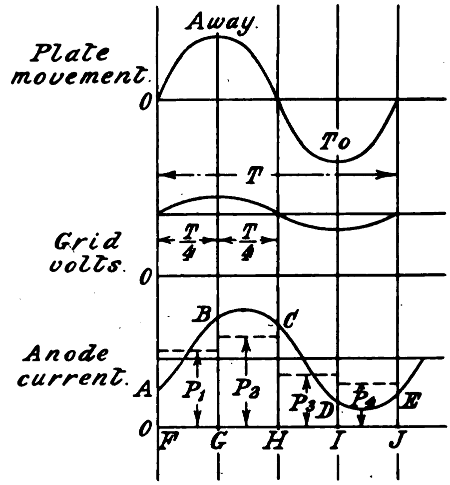


Fig. 11.

The direct anode current change, however, passes through the oscillatory coil, as well as the magnet, and so coincides with the position of the shoe that a small auxiliary pull is added by the tripping shoe. Decrement curves for the pendulum have been obtained, and are shown in Fig. 15.

From these curves it is apparent that the work which is imparted by the tripping shoe is exactly equal to the work performed by the pendulum on the input of the relay at two particular amplitudes, and also that at any amplitude between these two the

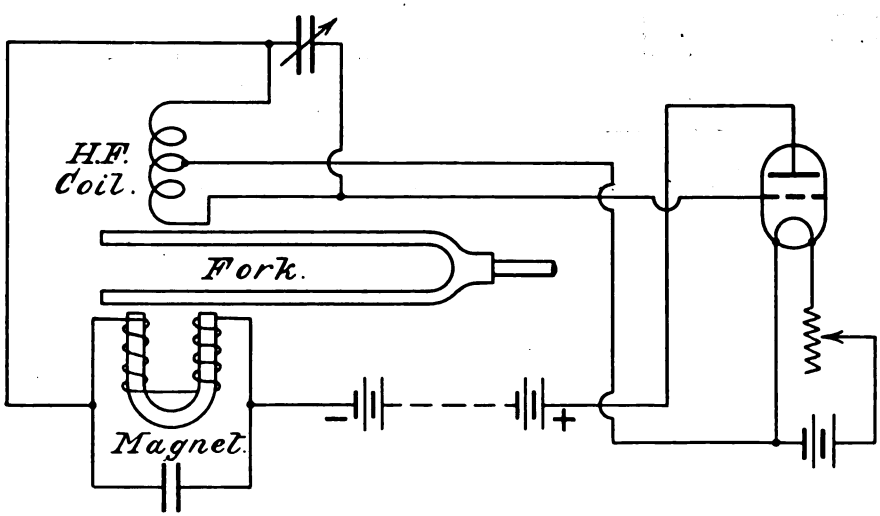


Fig. 12.

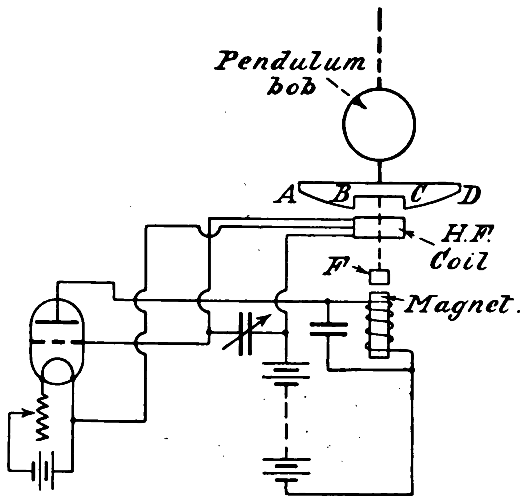


Fig. 13.

percentage error from the natural decrement is less than ¼ per cent. The maximum amplitude at which this is true is greater than any amplitude required in practice. At higher amplitudes the work performed on the pendulum by the tripping shoe is greater than the work which is taken from the pendulum, and the decrement consequently is less than that of the free pendulum at the same amplitude of swing.

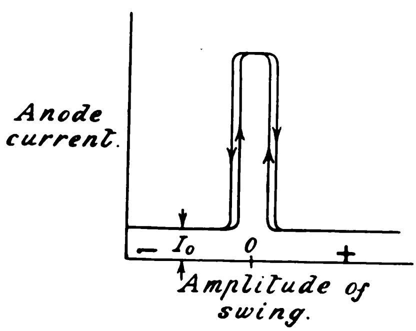


Fig. 14.

In practice the control of the amplitude is obtained by an adjustment of the filament brightness.

Conclusion.

In conclusion, it must be postulated that in any physical applications of the triode, such as those suggested, the calibration of the valve must never be depended upon. In every case this fact has been strictly borne in mind and the apparatus is calibrated in terms of a positive physical quantity. It has been found by careful experiment that the characteristics of a triode vary

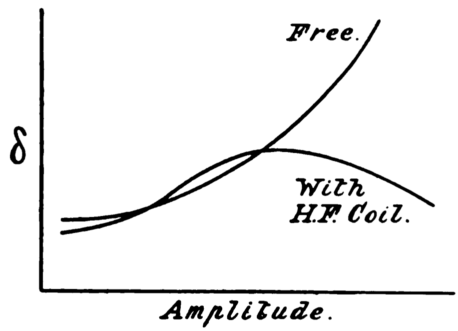


Fig. 15.

under normal usage during quite a short period of time. In less than fifteen minutes a change has been observed and the characteristics rarely repeat over periods of one hour.

Therefore, if a valve must be used, recalibrate each time the apparatus is used.

If a high inductance choke is inserted in the anode circuit, this must, in every case, be shunted by a small capacity to allow the high frequency pulses to pass through the anode circuit to maintain the oscillation.

It is hoped that these few illustrations will serve to demonstrate the fact that the scope of the thermionic vacuum tube is not limited solely to radio communication.

Note on Systems of Modulation Employed in Radio Telephony.

By H. S. WALKER, A.M.Inst.R.E.

We give below some notes on the most up-to-date practical systems employed to modulate a valve transmitter for telephonic transmission. The choke and grid control systems are fully discussed and the efficiencies of various methods compared, while mention is made of the well-known relay valve system of modulation.

AN ideal system for effecting modulation in radio-telephony has not yet been devised, but an approach to some such system would be the introduction of some agency or device whereby the voice might vary at will the ohmic resistance of an aerial system between rather wide limits. Such a system should act on the resistance of the radiating system alone and only affect the oscillator circuits as a result of a changing load in the aerial circuits. In addition, while there was a great increase or decrease in the ohmic resistance of the aerial, the constants of the modulating system itself should remain unchanged. Such a system has however yet to be devised, for while it is not a difficult matter to increase the resistance of an aerial, yet it is not practicable to decrease that resistance where much energy is employed.

Choke Control System.

As is well-known, all the broadcasting stations in this country use the choke-control system, but it does not seem to be generally realised that as much and sometimes more energy is absorbed by the modulators in a control system than is actually delivered to the oscillator. In addition to this, the valves employed for modulation purposes are of necessity the same size at least as the oscillator and two or more valves of this kind are used in parallel. Thus it is obvious that the outlay in valves in this system is very great. In addition, as already stated, the system is very wasteful in power: an experimenter having a generator available delivering 50 watts, would only have about 20 watts of energy available for the oscillator, the remainder being absorbed by the control system.

This system admittedly gives excellent speech, is robust and very stable, but the initial expense in valves and the consumption of energy involved, rule this system out, more often than not, for the experimenter with a limited pocket.

It is moreover doubtful if the quality of speech by this method far excels that given by a good grid-control system. Complicated musical sounds are not, as a rule, part of the experimenter's programme and stability can be maintained by the experimenter himself. Nevertheless, where expense is not such an important factor as reliability and quality, this system has undoubtedly much to commend it. In order that the operation of the system may be readily understood, Fig. 1 shows a sketch of a typical choke-control transmitter. It will be noted that three large valves are used in parallel in the modulating system and another smaller valve in addition to effect complete modulation.

In considering any modulation system there is naturally involved the question of the relative importance of the amplitude of the carrier wave in the non-modulating condition, and the variation taking place in this due to the modulation brought about at the transmitting station. For a given amplitude of non-modulated carrier wave which may reach a receiving station, the response in the telephone receiver is, of course, proportional to the change in amplitude of the carrier wave, this in turn depending upon the modulation at the transmitting station. The actual amplitude of the carrier is also an important factor. Even if complete modulation obtains, the current amplitude cannot have a minimum value less than zero or a maximum greater than twice the non-modulated value. It is well known with the choke-control system that energy from the modulators will cause an increase of energy in the oscillator when modulation takes place and it can be shown that an

instantaneous increase of 400 per cent. of power may take place in the oscillator circuits when complete modulation obtains. If, however, complete modulation does not obtain, an increase of 200 per cent. may take place notwithstanding. If then we adjust the oscillator circuits to give their maximum output during quiescent conditions, *i.e.*, when there is no modulation, it is obvious that the oscillator valves will be subjected to a very considerable overload when modulation takes place. Notwithstanding the fact that the overload is more or less intermittent it will no doubt tend to soften the oscillator valves, unless these be of sufficient size, *i.e.*, greater than would normally be required for a current of the normal non-modulating intensity. This is therefore a further source of expense in the choke-control system.

We may of course reduce the output of the valves to avoid overloading, but in that case the value of the non-modulated carrier will be less. As already stated, the current amplitude cannot have a maximum value greater than twice the normal non-modulated value, hence by reducing the output of the valves to avoid overloading the signal strength is likewise diminished.

Grid Control System.

The simple method of introducing the secondary of a modulation transformer in the grid circuit of a radio frequency oscillator valve is well known. Such a system, in its crude form, is not altogether satisfactory for use in sets utilising much power. The essential feature of the grid control method is that the electrical pulsations from the microphone are made to operate directly on the grid of the oscillator valve thus, in turn, controlling the amplitude of the energy delivered to the aerial. Such a system possesses the great advantages from the experimenter's point of view that the oscillator may be run full out as the change in amplitude of the non-modulated current may be arranged to be a decrease in amplitude only, when modulation is taking place. Secondly, no expensive power valves are employed for modulation purposes, neither is there any great deal of energy from the generator required to operate the modulator system.

There are several possible improvements on the original method of grid-control, but two of the best systems use a small valve, which may be of the receiving variety only, to assist modulation. The two systems

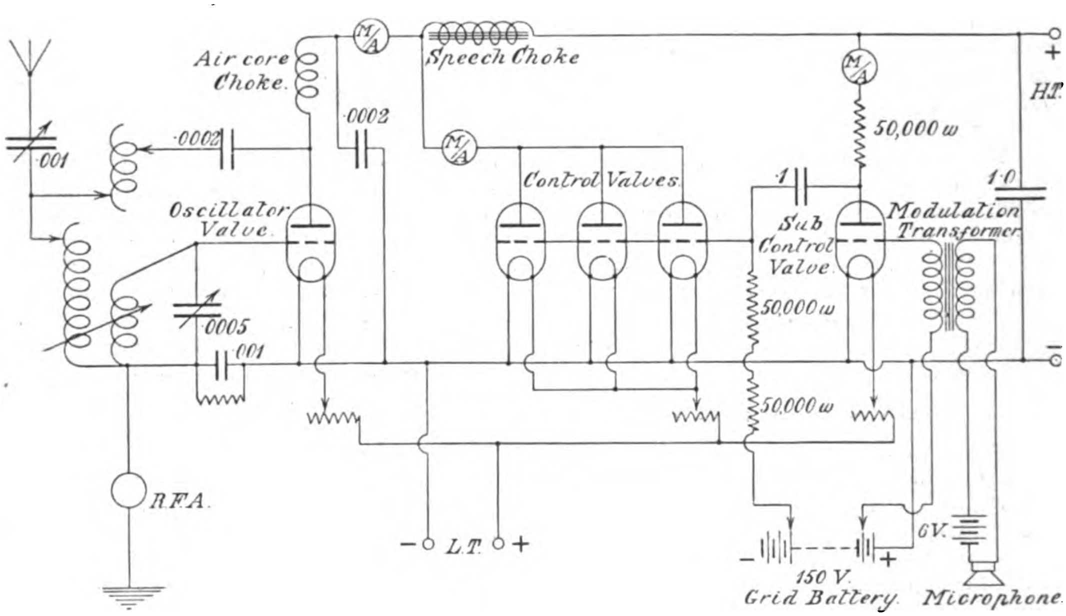


Fig. 1.—A Typical Choke-control Transmitter.

employ these valves in different ways: they may be described as

(1) Grid-leak method of modulation.
(2). Relay valve method of modulation.

The Grid-Leak Method of Modulation

is shown in Fig. 2. It will be seen that the usual grid-leak resistance is replaced by a small three-electrode valve and the plate-to-filament resistance of this valve is controlled by means of the voice through the usual modulation transformer connected to its grid. In this system the control valve functions as a variable resistance. It will be evident that for a given value of grid-condenser, the direct current potential of the grid of the oscillator valve will be determined by the magnitude of the inductive reactance in the anode-grid circuit, and also by the value of the grid-leak which latter consists of the plate filament circuit of the control valve. If the value of this resistance changes the direct current potential of the grid of the oscillator valve will correspondingly change, and control thus be effected.

The control valve used for effecting modulation by this method must be of such a nature that the valve will withstand the potential developed between the grid and filament of the oscillator; it must also be able to dissipate the heat developed by the grid-leak current.

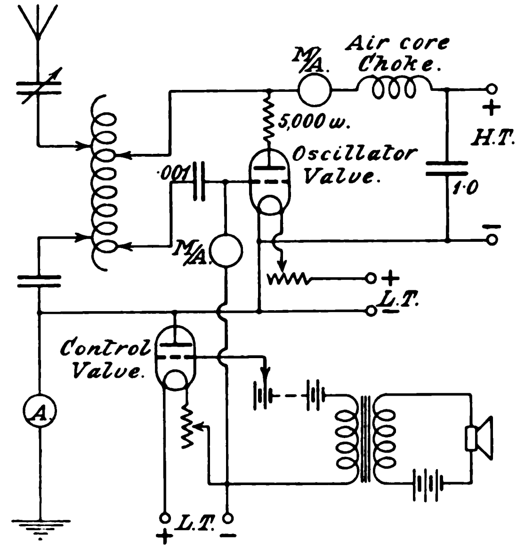


Fig. 2.—The Grid Leak Method of Modulation.

Relay Valve Method of Modulation.

This is shown in Fig. 3. It will be seen that the control valve has its anode-filament circuit connected directly across the grid filament circuit of the oscillator valve. The

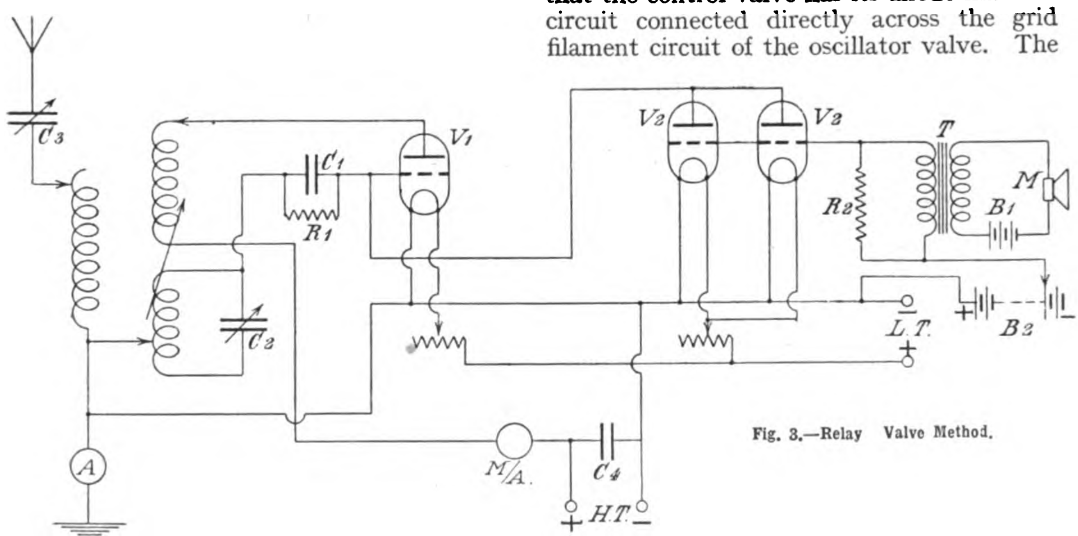


Fig. 3.—Relay Valve Method.

C1 = ·001 mf. 1,000 volts.
C2 = ·0003 mf.
C3 = ·001 mf.
C4 = 1 mf. 2,000 volts.
V1 = 0/150 valve.
V2 = L.S.5 valve.
B1 = 6-volt battery.
B2 = 45-volt tapped grid battery.
R1 = 5,000 ohms.
R2 = 50,000 ohms.
T = Modulation transformer 20/1. Primary resistance 1 ohm. Secondary 4,000 ohms.
A = Thermo ammeter 0—3 amps.
M/A = Milliammeter 0—150 milliamps.
M = High-resistance microphone.
L.T. = 12 volts.
H.T. = 1,500 volts.

grid of the control valve is connected to the secondary of a modulation transformer and coupled to the microphone in the usual manner. This system was the subject of a Patent No. 188,483, granted to the writer in 1921. It will be seen that in this system of modulation the modulating or control valve has its anode-filament circuit connected in parallel across the grid condenser and leak. The control valve therefore constitutes a variable resistance in parallel with the grid leak in addition to impressing pulsations of potential on the grid of the oscillator.

The control valve used for this system of modulation should possess similar properties to that used in the grid leak method.

here of the grid circuit of the oscillator is rather critical and should be adjusted so that the oscillator is just tending to lose radiation with a slightly weakened grid coupling.

It should be noted that all the systems of modulation mentioned above may be used in conjunction with any of the other well-known oscillating organisations other than those shown in the diagrams.

Comparison of Efficiency.

The above table shows a comparison of efficiency for the various systems of modulation described above. It should be mentioned that the choke-control method

INPUT POWER CONSUMPTION.
TABLE I.

	Choke-Control System.	Grid-Leak System.	Relay Valve System.	Average Aerial Current.
Power consumed by Oscillator Valves	80 watts.	100 watts.	110 watts.	2 amps.
Power consumed by Modulator Valves	80 watts.	none.	none.	——
Power consumed by Sub-Modulator Valve	15 watts.	none.	none.	——
Total Power Consumption ...	175 watts.	100 watts.	110 watts.	——

FILAMENT CURRENT CONSUMPTION.
TABLE II.

Oscillator Valve Filament ...	40 watts.	40 watts.	40 watts.	——
Modulator Valve Filaments.	120 watts.	5 watts.	10 watts.	——
Sub-Modulator Valve Filament.	15 watts.	none.	none.	——
Total Filament Consumption.	175 watts.	45 watts.	50 watts.	——

Tables Comparing Efficiency of Modulation Systems Described.

In practice, this system has been found by the writer to possess more stability and to give purer speech than the grid-leak method, though both methods have their own particular advantages and disadvantages.

Those wishing to experiment with this system will find in the list below Fig. 3 the sizes and capacities of various components connected as in the diagram, for an oscillator having a maximum of 100 watts applied to its anode. The adjustment

shows lower efficiency for actual wattage input, in addition to the initial expense for valves, etc., but the observations made in a preceding paragraph in this connection should be borne in mind. No allowance has been made for the inclusion of a master oscillator or "drive" as, although its use may be warranted in the case of a broadcasting station for commercial service, it is a source of considerable loss of energy and not necessary as a rule for experimental stations.

The Problem of High-Tension Supply.—III.

By R. MINES, B.Sc.

(*Continued from July issue, page* 585.)

III.—Chemical Generators.

(1) *The " Dry " Battery.*

THE primary battery is one of the oldest established methods of producing electrical energy. First used by Volta and Galvani, many different types have been developed ; but, except for the continued use of the Daniell cell for purposes of telegraph and railway signalling, it may be said that the Leclanché type is the most generally used. The small-size " dry " cell was developed to meet the need for portability (*e.g.*, in pocket torches) and is the kind that so soon won its way to popularity among a majority of radio workers as a source of high-tension supply.

The dry cell undoubtedly has the advantages of being simple in construction and use, and of necessitating no attention until the final replacement. Its capital cost is moderate and it has a reasonably long life on small sets, if of a reputable make. There remain, however, certain inherent disadvantages. The output P.D. of a Leclanché cell falls continuously during discharge over a range as great as 2 : 1, and, further, a point in the discharge is soon reached where, due partly to inevitable " local action," the P.D. becomes unsteady, causing troublesome " noise " and unstable operation of one's wireless apparatus. These conditions necessitate the continual addition of new cells to the battery and the scrapping of " noisy " ones long before their economical life is over. These cells show a deterioration of similar nature with age, irrespective of whether they are in use.

When the demands for high-tension power grow beyond the few score volts and the few milliamperes of the broadcast receiver the advantages of the dry battery method begin to disappear. An increase in the current demand necessitates using a larger type of cell, to avoid temporary polarisation setting in after a short period of use, and to secure reasonable life and freedom from " noise," and the cost of renewal will also be proportional to the P.D. in use. It soon becomes more satisfactory, therefore, and cheaper in the long run to instal some other method of supply.

(2) *The "Wet" Battery.*

The original types of " wet " cell such as mentioned above are not suitable material

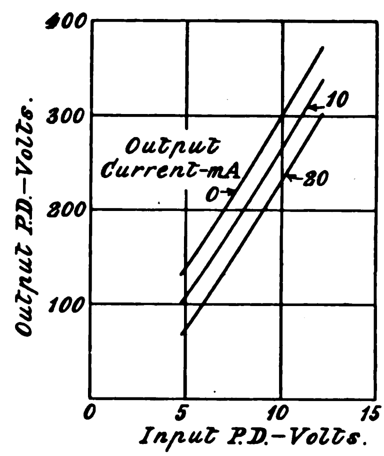


Fig. 1.

for building a high-tension battery ; but following the advent of the small wet Leclanché cell, specially designed for wireless purposes, the installation of a wet battery is a practicable proposition, since it has become comparable in capital cost and in space occupied with a dry battery of similar power output. The wet battery has advantages over the dry battery—in general it will give a steadier output, and maintenance, though more troublesome, is not so expensive, as the active materials (zinc, electrolyte, and depolariser) may be renewed separately as required. An instance of the use of larger size cells of the wet type is the high-tension

battery described by N. K. Jackson in EXPERIMENTAL WIRELESS for November last.

There has recently been developed (in France, by Féry) and now marketed in England under the name of the "A.D. Primary Cell," a new type of wet cell, which uses the Leclanché combination (zinc—ammonium chloride—carbon), but which dispenses with the usual solid depolariser. Instead of a thin carbon rod or plate, surrounded by a porous vessel containing a chemical oxydising agent (manganese dioxide) as depolariser, the positive electrode consists of a large block of specially-prepared porous carbon, which, by its catalytic property, allows the oxygen of the atmosphere to depolarise the cell. On test, it is found that after an initial quick drop the P.D. of these cells remains practically constant until the whole of the zinc electrode is consumed, the value being about one volt, and the discharge (in the case of a telegraph battery) being about 20 m.a. An account of these cells (and some further tests on them) is to be found in the *Electrical Review* for March 14, 1924. An illustration is shown also of a high-tension battery designed for wireless work,

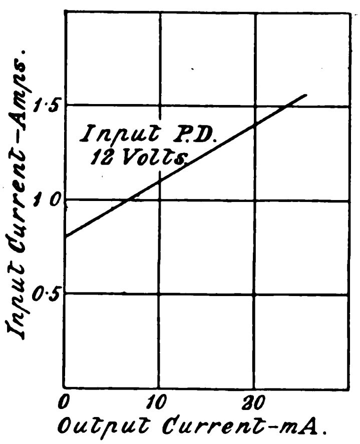


Fig. 2.

a box of cells (in the "dry" form) rated to give 40 volts. It will be seen that the advantages of these cells over the original manganese dioxide depolariser type, *viz.*, constancy and economy, are especially important for wireless purposes.

(3) *The Secondary Battery.*

The "lead-acid" storage battery or accumulator is already familiar to radio workers in connection with supplying valve filaments, but not many use it as yet for high-tension supply. This may be attributed largely to its comparatively recent development, in a form suitable for wireless work, and its higher capital cost even in this form. There are the further disadvantages of excessive weight, and the necessity for regular attention if maintenance costs are to be kept at a minimum.

In the "nickel—iron—alkali" type of battery, however, these disadvantages have been largely eliminated. The weight for a given output has been reduced, and the attention required is very little, coupled with a much longer life. Unfortunately, the initial cost is considerably higher than for the "lead-acid" type.

The great advantages of the secondary battery are more apparent on the electrical side. It has long been recognised among research workers as the best obtainable source of electrical energy, and, in fact, is used as the only method of obtaining a perfectly constant and reliable source of electricity. It will be seen, therefore, that this method is inherently the best suited to the supply of high-tension power for radio purposes.

A further discussion on the relative merits of primary and secondary batteries, together with details of different kinds of the former, will be found in an article by Ward and Goldsmith in *World Power* for January, 1924.

Electro-Magnetic Generators

The high-tension generator was principally developed for the application of wireless telegraphy to aircraft, it having been found necessary to find a substitute for the dry battery method which up till then had been the only one available. This fact alone emphasises its superior reliability and freedom from maintenance troubles, two factors of prime importance in the Services.

(1) *Dynamos.*

Aircraft generators are usually wind-driven, and the first machine to use this drive was the "52 A" alternator; this was not a high-tension machine however—it was used in conjunction with a transformer. Its output was 20 amps. at 10 volts and 660

cycles per second, and its weight was 8 lbs., giving the remarkable figure of 25 watts per lb., which is easily ten times that obtainable from a lead-acid accumulator at its maximum discharge rate.

Following this were the actual D.C. high-tension generators. One type, by B.T.-H., gave 40 watts at 600 volts, with a weight of 18 lbs.; another, by Newton, gave 75 watts at 1,200 volts, weight 11 lbs. These machines were produced early in 1918, and, naturally, they have been improved upon since that time.

As a source of high-tension power, the generator may be said to rank next to the secondary battery from the electrical point of view. The constancy of the P.D. supplied by the machine is little affected by the amount of power drawn from the machine, being mainly dependent on the constancy of the driving power; there is no irregular falling off, as with the dry battery method, and no powerful periodic pulsation, as with the rectifier methods used on alternating supply. On the other hand, it is inherent in D.C. generators that they produce a "ripple," due usually to the armature slots, and sometimes to the commutator bars. This ripple is an alternating P.D. superimposed on the steady value, and in some cases may be a great trouble if the radio apparatus is connected direct to the generator. Usually, however, the frequencies present in the ripple are high, and the amplitude limited, so the problem of its elimination by means of a filter is, as we shall see later, comparatively easy.

(2) *Motor Generators.*

Motor generators were developed on similar lines to the dynamos; one example, by Newton, gave 100 m.a. at 1,200 volts when supplied from a 12-volt battery, its speed being 6,000 revs. per min., and its weight 12 lbs. (giving a figure of 10 watts per lb.—note that this includes the driving motor). This machine was designed for use on "lighter-than-air" aircraft, and hence "sparkless commutation" was an essential condition.

The self-contained motor-generator unit is naturally better suited to the radio experimenter's requirements than the dynamo, which has to be fitted with a motor or other driving device, and it is possible nowadays to select from a range of models differing

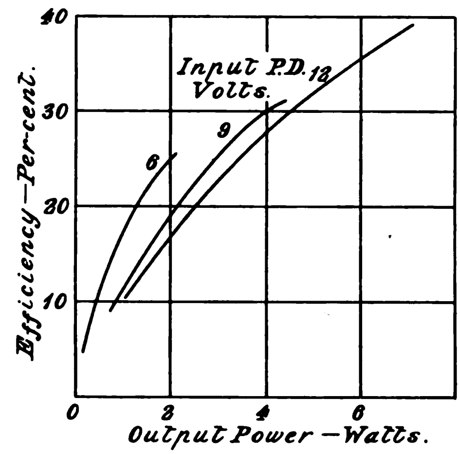


Fig. 3.

in P.D. and power outputs—a typical range is 40 to 300 watts, giving P.D's from 700 to 1,200 volts. Such machines cover well the requirements of the larger experimental transmitting stations, but they leave the small "10-watt" transmitters and the receiving stations uncatered for. Of course, the larger machines will not fail to supply the smaller sets, but, owing to the unfortunate fact that such machines are relatively very expensive, the radio worker tends to look elsewhere for his small-power high-tension supply.

(3) *Rotary Transformers.*

In this apparatus the two machines, the motor and the generator, are now merged into

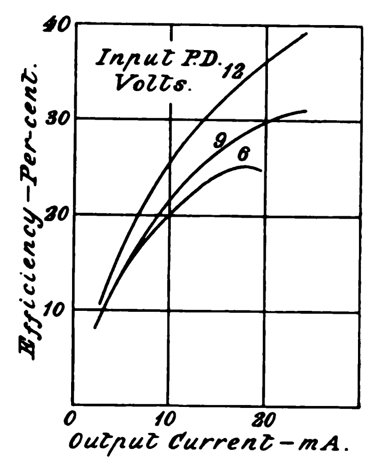


Fig. 4.

one unit. This straightway entails disadvantages:

(1) The possibility of a failure (*e.g.*, of insulation) on the generator side affecting the motor windings, and the impossibility of using a high P.D. (other than that generated) between the two elements, as is sometimes necessary when "series valve" circuits are used.

(2) The inability to control the value of the output P.D. independently of the driving side of the machine; however, it is usually possible to control the supply to the motor side.

Nevertheless, there are distinct advantages in this system:—

(1) The overall efficiency of conversion (from low-tension power to high-tension power) will be higher, due to the use of one field system and one armature core, instead of two of each, in which parts the major losses of power take place.

(2) A corresponding reduction in the weight and the size of the machine for a given output, or, alternatively, the use of a lower running speed, giving a more reliable machine. From the point of view of the radio worker not the least advantage of a reduction in speed is the quieter operation of the machine.

(3) If, as is the usual practice, the motoring and generating wires are wound in the same slots of the armature core the ripple produced may be considerably lessened; this effect is most valuable when the machine is on load, for under this condition a plain generator tends to give an enhanced ripple due to "armature reaction."

Of modern rotary transformers one example is that made for Marconi by Mortley, Sprague, which gives 72 watts at 1,200 volts, taking about 13 amps. from a 12-volt supply (*i.e.*, efficiency 46 per cent.). This type of machine, however, still does not cater for the small-power requirements of the radio worker of to-day.

Difficulties in Design of Small Machines.

It has been said that one of the factors against the use of the high-tension machine is its cost, and it will be seen that one way of reducing cost is to reduce the size of the machine to the minimum that will deal with the electrical loading required. Another factor to be considered by the radio worker is the power input required to run the machine—this is commonly as much as half the maximum (full-load) value even when the load on the output (H.T.) side has been reduced to zero. This factor of itself necessitates the reduction of the size (rating) of the apparatus to the minimum, as above, apart from the question of its efficiency when on full load. It will be evident, too, that if in designing smaller machines the efficiency is allowed to fall (as it tends to do rapidly, due to the difficulty in reducing the losses) the advantage gained in reduction of input power may be largely nullified.

One of the sources of loss of power in the electro-magnetic generator is the field-magnet system. This has been made of electro-magnet type since quite early days of dynamos, partly to permit control of the machine by variation of the field strength, but also to economise material and bulk of the machine. In the case of the rotary transformer type of machine, there is no call for variation of field strength. From the electrical point of view, therefore, the substitution of a permanent magnet field is possible, with the resulting elimination of the field magnet winding and the power consumed in its excitation. From the mechanical point of view, such a substitution involves considerable increase in size and weight if tungsten steel magnets are used; but the introduction of cobalt steel for magnets has enabled the substitution to be made with little change in weight.

The M.L. Anode Converter.

The M.L. Magneto Syndicate, who for some time have been producing magnetos with cobalt steel magnets, have applied this principle successfully to the rotary transformer in their "Anode Converter." This application and other refinements of design have led to the production of a machine of much smaller power rating and with an efficiency comparing favourably with the larger machines, examples of which have been quoted. Anode converters suitable for transmission purposes are in production, and there are three standard sizes now on the market for receiving and amplifier work, particulars of which I have arranged in the table on the following page.

Through the courtesy of the manufacturers the author has had the privilege of using a "C" model anode converter, and in

MODEL.	PURPOSE.	OUTPUT. P.D.	OUTPUT. Current.	INPUT. P.D.	INPUT. No-Load Curr.
		Volts.	m.a.	Volts.	Amps.
A.	Receiving	35 to 70	15*	6	0·9
B.	Do. and Power Amplifiers ...	60 to 120		6	1·1
C.	Do. and Do.	150 to 300		12	0·8
D.	Transmitting	250 to 500	20	12	1·2

* This is the maker's rating, for continuous loading, and with the machine in position in its box.

Quantity.	Unit.	Dry Battery.	Wet Battery.	Lead Accumulator (10 hr. Discharge).	Alkali Accumulator (4 hr. Discharge).	Rotary Transformer (Model C.)
Output	m.a.	5	10 to 20	100 to 200	500	20
Weights	lbs./volt. lbs./watt.	1/10 20	¼ to 1 25 to 50	¼ to ⅜ 2½	(⅜) (1½)	1/20 2½
Costs	shillings/volt. £/watt.	¼ 2½	⅜ to 1½ 3½	1 ¼ to ½	2¾ ¼	1 2½

In the above table the various methods are arranged in the order of the length of their useful life, that of the generators being indefinitely long.

order to determine to what extent this machine "filled the gap" in the matter of a satisfactory low-power high-tension supply for radio purposes it has been tested at East London College by Mr. M. Stern, B.Sc., who has kindly placed the results at the author's disposal.

The machine is provided with a variable resistance (of a type used for controlling valve filaments) connected in series with the motor armature; this enables one to vary the P.D. acting across the motor terminals, and hence to control the output (high-tension) P.D., over a range of from half value to full value. Fig. 1 gives the relationship; the three curves are for different values of output current.

Fig. 2 gives the relation between input current (to motor) and output current (high-tension). Here the input current is a measure also of the input power, since the P.D. acting on the motor is held constant at 12 volts; it will be seen that the input power corresponding to zero output (*i.e.*, "no-load" input) is over half its value for full load, indicating a high proportion of lost power.

However, considering the difficulties inherent in the production of machines of such small ratings, the efficiency attained quite a high value at full load; this may be seen from Figs. 3 and 4. Three curves are shown, for three values of the P.D. across the motor armature (as controlled by the resistance). The efficiency given is that of the machine only, *i.e.*, taking no account of the power loss in the resistance; this loss is zero, however, for the 12-volt curve, and similarly for the 6-volt curve if a 6-volt supply is used.

The machine as supplied is mounted on rubber buffers inside a cast aluminium box, the lid having a machined joint; this reduces external mechanical noise of the machine practically to nil. This box houses also a complete filter circuit. The machine in question has been used on a power amplifier (audio frequency), and on receiving circuits (including a sensitive super-regenerative set), and the effectiveness of the filter in reducing the "machine note" or ripple was demonstrated to be sufficient for radio purposes.

The author has measured the ripple under varying circumstances, using a Cathode-Ray Oscillograph. The magnitude of the ripple is expressed by the percentage variation of the P.D. on either side of its mean value. With the filter disconnected the ripple is 15 per cent. at full P.D. and no load. With the filter connected (which here is almost equivalent to putting a condenser across the terminals) and measuring the ripple across

the machine terminals as before, the ripple is reduced to 4 per cent. at full P.D. and no load; at full load it further decreases to 3 per cent. If, now, with the filter in circuit as before, the measurement is made at the output terminals of the filter (whence supply is taken for radio apparatus), the amount of ripple is found to be under ½ per cent.

Some Comparisons of Generator Methods.

Some approximate particulars of weights, capacities, and costs for some of the different methods of high-tension supply have been extracted from catalogues of the following makers:

Dry Battery: Ever-Ready.

Wet Battery: Siemens (Leclanché) and Darimont.

Lead Accumulator: Hart, Fuller (block) and Exide.

Alkali Accumulator: Alklum.

Rotary Transformer: M.-L. (Anode Converter.)

The Poulsen Arc.

By DALLAS G. BOWER.

The function of an arc as a generator of continuous waves is treated in an elementary manner in the following article. Methods used at commercial stations are also briefly outlined.

It is the object of the writer in this article to explain the function of the Poulsen arc system for producing continuous wave oscillations. It is felt that many amateurs are not entirely acquainted with the arc, and a short explanation of its working may be of interest. There are three methods commercially used for communication by continuous wave radio, namely, the thermionic triode, the Poulsen arc, and the Alexanderson high-frequency alternator. The function of the arc will now be explained.

Suppose two electrodes to be placed in proximity to each other, one made of copper and the other of carbon, and let them be connected to a high voltage D.C. source as shown in Fig. 1. The positive pole of the source is in contact with the copper and the negative with the carbon. If the carbon is gradually placed nearer the copper a large current will flow which will heat up these two electrodes to a very high temperature. In practice the anode (positive copper electrode) is cooled by water, otherwise it would melt. The cathode, or negative carbon electrode, gets white hot at its tip, and in consequence of this fact shoots off a great number of electrons. If the distance from the cathode to the anode is made larger these electrons will travel from the cathode to the anode. Hence a collision will occur between the electrons and air molecules, thus positive and negative ions are formed. This produces a gaseous arc which carries a convection current consisting of negative ions and electrons moving to the anode and positive ions moving to the cathode. The distance between the electrodes can be prolonged until the energy supplied to the aforesaid electrodes is insufficient to maintain the arc. The resistance of an arc of this nature does not remain constant, but drops as the current through it is increased,

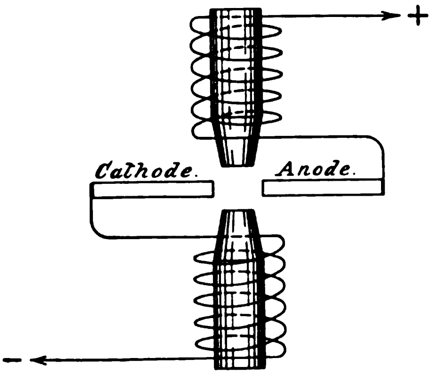


Fig. 1.

and rises as the current is decreased. It will be seen that unless the positive ions are absorbed quickly by the cathode, and the negative ions by the anode, on an increase in convection current clouds of positive ions will gather around the cathode and negative ions around the anode. This tends to reduce the P.D. across the gap, and thus the resistance is lowered. The voltage drop across the arc varies inversely with the current. An arc of this kind can be made to produce undamped oscillations, providing it is placed in a circuit possessing inductance and capacity. Referring to Fig. 2 it will be seen to have a D.C. supply, two iron core chokes L_1 and L_2, an arc A, and a circuit LC with a suitable switch at Q. Owing to there being a P.D. across the arc the condenser will commence to charge up. It will be seen that this charge cannot come from the D.C. source on account of the inductance of the two chokes. It will therefore have to come from the arc itself. During this charge the switch Q is, of course, closed.

As the charge is increased the current in the arc falls off, the P.D. across it rises, hence a further charge into the condenser. The voltage across the condenser eventually becomes the same as that across the arc. Now the inductance L tends to make the current in the arc keep on, with the result that a further charge is introduced into the condenser. Eventually the voltage across the condenser reaches a maximum, and will fall off as the condenser discharges, and it will be seen that the discharge of the condenser increases the arc current. This will result in a decrease of P.D. across the arc, and allow the condenser to discharge still further. When the condenser is fully discharged the inductance L comes into operation and starts to charge up the condenser in the opposite way. Providing the arc is kept burning, the condenser current will become oscillatory, and continuous oscillations will be set up in the circuit ALC. The production and building of oscillations may be made more clear by referring to Fig. 3. At the point marked O the switch Q (Fig. 2) has not been closed. The current through the arc is 15 amperes at a pressure of 250 volts. At A the switch is closed, and a current of 3 amperes is flowing into the condenser. Thus the arc current is —3 amperes, which is 12 amperes. From the arc voltage curve it will be seen that the arc voltage has increased to 280 on account of the decrease of arc current. The P.D. across the condenser will now rise to the same as that across the arc. At B it will be seen that the condenser current has fallen to zero, while the P.D. across the condenser has risen to 460 volts. At this state of affairs the arc current and arc voltage are their normal value, as shown. After B, the P.D. across the condenser is greater than that across the arc, so current starts to flow out of it into the arc. This lowers the P.D. across the arc. At C the arc current has risen to 4 amperes by reason

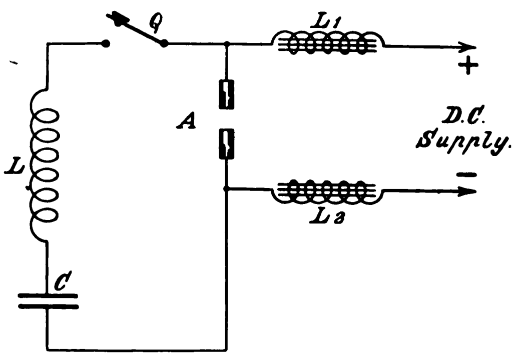


Fig. 2.

of the fact that the condenser current flow is of the same figure. It will be seen that the arc voltage and condenser voltage are now the same. After C the energy stored in the magnetic field of the coil L tends to keep the current flowing out of the condenser and reduces the P.D. across it to zero. The complete operation will now commence again. It will be seen that the condenser current curve is in exact phase with the arc voltage curve. It is the fact that the condenser current is in phase with the arc voltage that maintains oscillations in the circuit ALC.

It must be remembered that any arc will not maintain oscillations in an oscillatory circuit. Various precautions have to be taken into account. The most important matter for successfully running an arc is to keep it cool. If the arc is not able to radiate its heat away quickly enough the change in arc voltage will lag behind the change in arc current, and only feeble oscillations will be set up. In commercial practice

three methods are used for keeping the arc cool, namely, burning the arc in hydrogen gas; burning the arc in a strong magnetic field; water-cooling the chamber containing the arc and cooling the tip of the anode

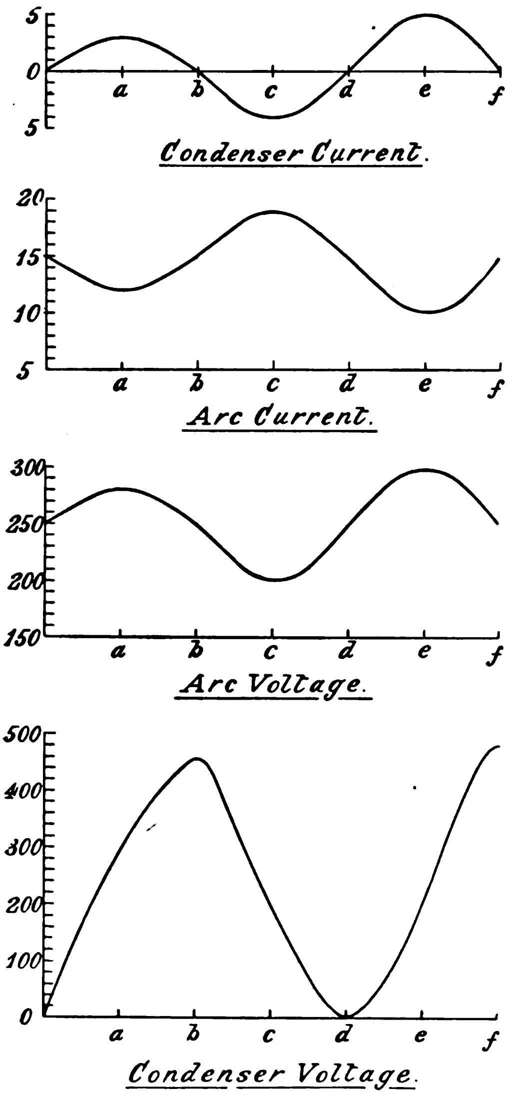


Fig. 3.

with water. Referring to Fig. 1 it will be seen that the arc is placed in suitable position to two field-magnets, in order to produce a strong magnetic field across it. The windings of the magnets are wound over soft iron cores whose tips project near the arc electrodes. These windings are connected in series with the D.C. supply and the arc electrodes. They sometimes serve a dual purpose as they also function as the chokes shown in Fig. 4. The arc, then, will burn in a strong magnetic field. Providing the field windings are connected correctly, the magnetic influence on the arc tends to bow it upwards. It will be understood that the arc under these conditions is much longer for a given distance between the electrodes, so it will therefore have more chance of radiating its heat away quickly. The magnetic influence also tends to make the arc burn on the top edge of the electrodes, and it is therefore stabilised.

For successful operation it is absolutely essential that the arc be steady in burning, and to this end the carbon must burn evenly. This is usually accomplished by rotating the carbon by some auxiliary means. The object of burning the arc in hydrogen gas is to convey the heat away more quickly. Since hydrogen gas is lighter than air this operation is successfully accomplished. If the arc is burnt in air a number of positive ions from the cathode combine with negative ions of oxygen and so produce carbon dioxide, and so many of the ions that would have gone to reduce the P.D. across the gap are lost. In order to keep the whole of the arc equipment cool distilled water is pumped round the sides of the arc chamber and the tip of the anode. The water must, of course, be absolutely pure, otherwise the anode would have a path to earth. The length of the wave transmitted by the Poulsen arc is dependent on the constants, etc. In order to signal with the arc a system known as the "Marking and Spacing Wave" is adopted. It is not possible to make and break the D.C. supply circuit, as, of course, the arc would go out. In the marking and spacing wave system a portion of the inductance is shortened and so alters the wave-length transmitted. The antennæ is kept in an oscillating condition, when the key is up, at a given wave-length. When the key is down a portion of the inductance in the antennæ circuit is shorted and so a different wave transmitted. This wave is called the marking wave and is the actual signal. It is, of course, of a lower wave-length than the spacing wave. The difference in fre-

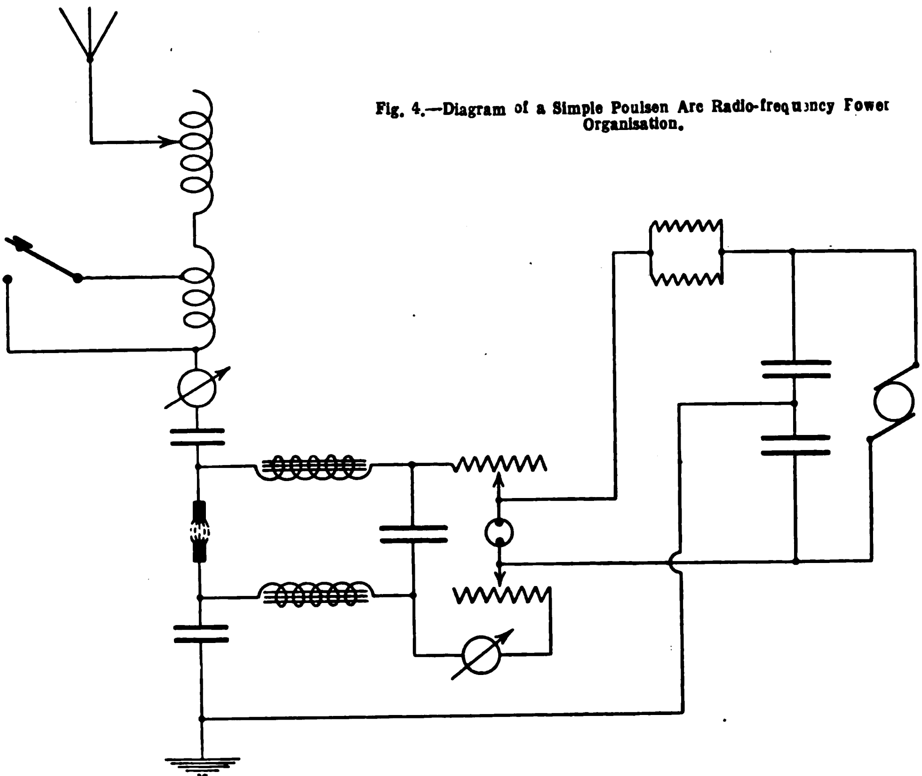


Fig. 4.—Diagram of a Simple Poulsen Arc Radio-frequency Power Organisation.

quency between the marking and spacing wave is about 2,000. The type of equipment usually employed in commercial working is shown in Fig. 4. The various apparatus is readily discernible. The D.C. circuit is usually fed by a D.C. generator. The arc starter, which is shown in the circuit diagram as a double-pole resistance is used to prevent a violent rush of current when the arc starts. As the arc starts functioning the resistance is decreased. A D.C. ammeter is placed in the negative pole lead of the D.C. circuit, and a R.F. ammeter in the antennæ circuit. When the arc has been adjusted this meter will read the R.M.S. value of the D.C. meter, *e.g.*, D.C. meter reading = 20 amperes; antennæ meter will read 14 amperes. The usual protection of the D.C. supply from the oscillatory circuit has to be taken into account. This is effected by shunting a series of condensers across the output terminals of the D.C. generator. The bank is earthed as shown. The arc functions most efficiently on long wave-lengths and will not work very well below 1,500 metres wave-length. As the transmitting frequency is increased, and hence the wave-length lowered, the arc voltage tends to lag behind the arc current and so the arc becomes unsteady. Recent experimental work has been conducted, however, using the arc on very high frequencies with quite considerable success.

A Vernier Condenser with Micrometer Adjustment Suitable for Use on 100 Metres.

By G. A. V. SOWTER, B.Sc. (2OS).

No doubt many amateurs have found tuning to be difficult on 100 metres and below. We give here information on the design and construction of a condenser which is particularly suitable for tuning purposes on very low wave lengths.

THERE must exist a large number of amateurs who have interested themselves in the reception of trans-atlantic signals on about 100 metres during the last few months, using the conventional circuits, and, no doubt, many of them have experienced the difficulties of obtaining that precise tuning necessary on these wave-lengths. It is frequently found that capacity effects due to the body of the operator may entirely detune the set, and as the result of a fair amount of experience, including the reception of KDKA on 100 metres more than a year ago, the writer has evolved the following novel condenser, to which he attributes the overcoming of most tuning difficulties.

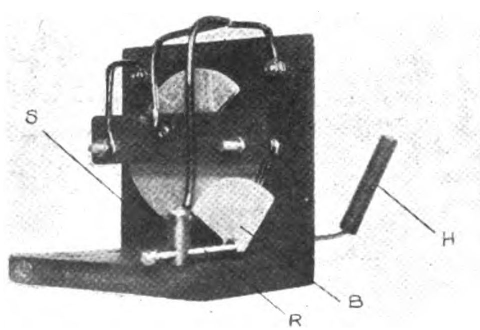


Fig. 1.

As indicated in Fig. 1, this condenser is of the normal two-plate vernier type, but with the refinement of a small auxiliary plate B connected electrically to the moving elements through S. Sector B can be caused to rotate through 90° by means of the handle H, the bearings being a small bush in the ebonite front and a spring terminal S in the rear. The novelty of this auxiliary is that the distance between the fixed plates and the sector B can be adjusted to any value between 1-16th of an inch and two inches by merely depressing S and pushing the rod R into the desired position. To reduce the minimum of this condenser to as low a value as possible the moving plates rotate about an axis which is not at the geometric centre of the fixed plates; this is clear from the dimensioned figures (Figs. 2a and b).

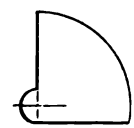


Diagram showing the shape of the Plates.

Accurate measurements of the values of capacity were made on a modified form of Wien Bridge, and the following results obtained:

Maximum capacity 41 $\mu\mu$F.
Minimum capacity 7 $\mu\mu$F.

When B was 1-16th inch from the fixed plates a 90° movement of H caused a variation of capacity of 3·5 $\mu\mu$F.

When this distance was two inches, the variation was 1 $\mu\mu$F.

Variation of capacity due to translational movement from "fully in" position at X to "fully in" position at Y (Fig. 2a) was 5·5 $\mu\mu$F.

As is natural, the condenser was first constructed, and these values measured subsequently. Consideration of the value of minimum capacity would indicate the advisability of making the distance between the geometric centre of the fixed plates and the axis of rotation of the moving ones ½″ instead of ¼″ as in the original condenser.

It is seen that a 90° rotation of the sector B can cause any variation of capacity from 1 to 3·5 $\mu\mu$F., and since it is a comparatively easy matter to adjust the position of H to within, say, 5°, even when using a long ebonite rod for this adjustment, it follows

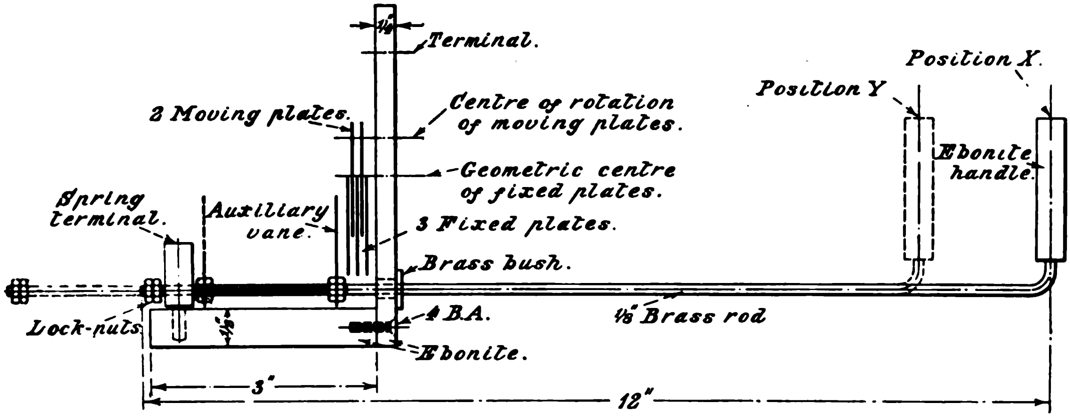


Fig. 2 (a).

that a setting of the condenser to within 1-10th $\mu\mu$F. is not difficult.

It is more than probable that the variations of capacity due to B are not directly proportional to the angular movement of H, but since this is not essential for the purpose in question, no effort was made to effect this.

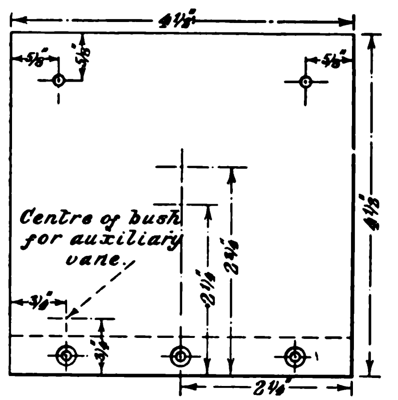
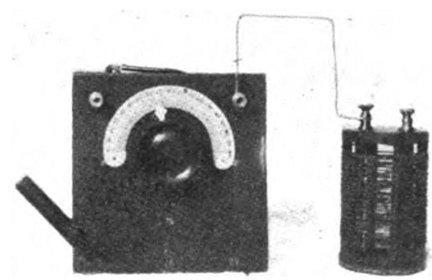


Fig. 2 (b).

In practice, it was observed that on 100 metres the tuning had to be exact to within 1 $\mu\mu$F. for the station to be audible, and that for best results adjustment was necessary to within about 1-5th $\mu\mu$F., but, obviously, these figures will depend upon the other constituents of the tuning circuit.



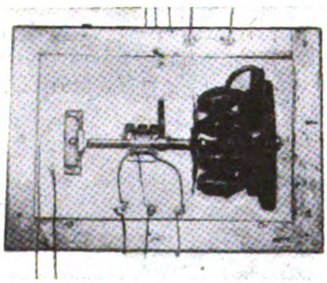
The Complete Condenser.

A Simple Rotary Rectifier.

By A. BUTEMENT.

One of the greatest problems of the transmitting experimenter who possesses A.C. mains is efficient and inexpensive rectification in order to give him D.C. for his transmitter. We give below a description of a rotary rectifier, which is one of the most efficient of its kind.

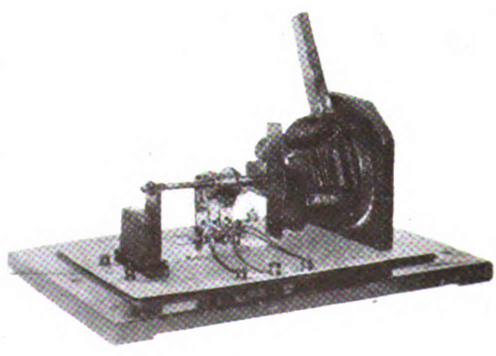
A RECTIFIER such as is described here is very useful to the radio experimenter for obtaining D.C. from A.C. mains for accumulator charging, etc. The system may also be applied to a variety of other purposes.



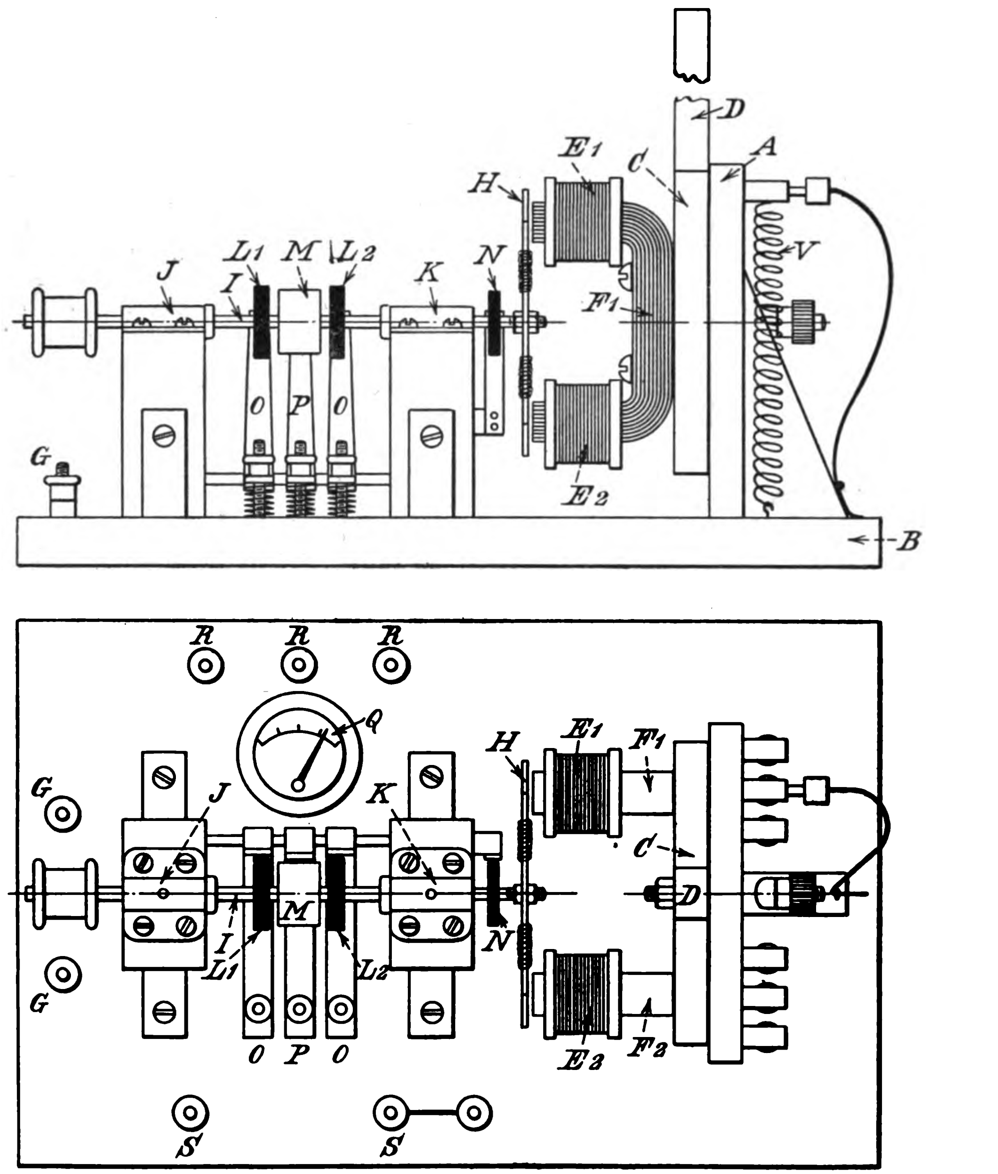
The Completed Rectifier.

With reference to Figs. 1 and 2, no dimensions are given, but only a diagram approximately to scale, as every amateur would make this machine up to suit the materials in his possession. A is a wooden support fixed vertically to a substantial base B, and kept perpendicular by a bracket at the back. Behind A a tapped resistance V for varying the current through the cells on charge is mounted. C is a disc of wood with a handle D extending, of which the use will be subsequently described; C is bolted through its centre, about which it can swivel, to the support A. E_1, E_2, etc., are bobbins, four in all, wound with insulated copper wire to suit the voltage applied to them. If about 16 volts is to be used, they may contain $\frac{3}{4}$ lb. of gauge 22 D.C.C. between them, or 3 ozs. each. F_1 and F_2 are cores made of soft iron, and bent as indicated in the figure. These, on which the bobbins are fitted, are screwed to the bat-shaped piece of wood C, so that the centres of the four bobbins are equally spaced round a circle whose centre is the pivot holding C to A. These four magnets are connected in series, so as to give N, S, N, S, poles as one goes round the circle; the ends are connected with flex to the terminals G.

H is a piece of sheet iron, say 1-10th inch thick, cut to the shape indicated in Fig. 3. This is bolted to a shaft I, which is mounted on two firm bearings J and K. A wooden cylinder is fixed on the end of the shaft, and is used for starting up. A cotton reel will do. Two slip rings L and an eight-pole commutator M, of substantial design, are fixed between the bearings on the shaft. (The slip ring N does not concern us here, but will be dealt with later. This applies also to the winding on H.) The two slip rings L are connected to the commutator in a manner indicated in Fig. 4. Two pairs of opposite sections are connected to the two slip rings, and the other four alternate sections are dead. O and P are brushes making contact with L and M respectively; they may be of any design, but should be capable of fine adjustment. Q is a moving coil ammeter, used to measure the current flowing through the accumulators and should not be omitted. R and S are terminals connected as shown in Fig. 5.



The Rectifier Showing Mounting.



Figs. 1 and 2.—Diagram Showing Construction of the Machine.

A fuse should be included in the accumulator circuit in case of accidents.

A transformer will also be needed to step the main's voltage down to that required for the accumulators ; if this is a six-volt battery, then the voltage should be stepped down to 16 volts, 8 volts either side of a central tapping.

If a central tap is not available, then 8 volts may be applied to the slip rings and D.C. obtained from two brushes, exactly opposite to one another, on the commutator.

To start the rectifier, switch on the transformer and the current to the bobbins E_1, E_2, and give the rotor a twist, by drawing the hand over the cotton reel. After a little experience it will be found that it is quite easy to start the rotor at the correct speed to

fall into synchronism ; this will probably be accompanied at first by a rhythmic bumping, something like a car starting up, but this should quickly die out as the motor truly synchronises. It will then run at a steady speed, at half the frequency of the mains, *i.e.*, if the input is 50 cycles, the motor will make 25 revolutions per second, or 1,500 revolutions per minute. Harmonic speeds are possible, but are rarely met with.

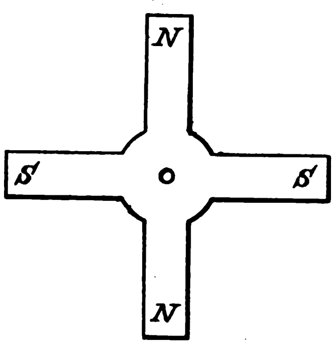


Fig. 3.—The Armatures.

When everything is steady the brushes may be lowered into contact with the slip rings and commutator, and the output terminals dipped in acidified water to find the polarity (the pole which gases most being the negative). Having found the polarity, the accumulators may be connected (positive to positive) in circuit, with the maximum value of the resistance in circuit. The field coils are then rotated by the handle until sparkless running is obtained, and the current through the cells increased to the value specified on them.

If the rectifier is made as described above, and if the four bobbins form exactly a square,

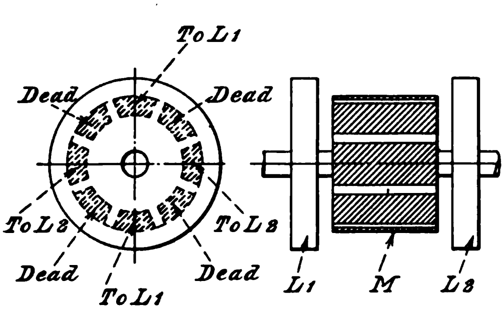


Fig. 4.—Method Used to Fix the Slip Rings on the Commutator.

there is no reason why it should not give satisfactory and reliable results.

Now, if the four points of the rotor possessed a permanent magnetic polarity, as shown in Fig. 3, the motor would obviously run much more smoothly, also the polarity could be determined once for all. In practice, however, such magnets would be difficult to obtain, and the continual vibration would quickly depolarise them. But, if the rotor is wound, and the four bobbins thus formed are connected in series to give the polarity indicated in Fig. 3, and the two ends connected to the slip ring N, and the shaft, and if the cells are connected to the bearings, and

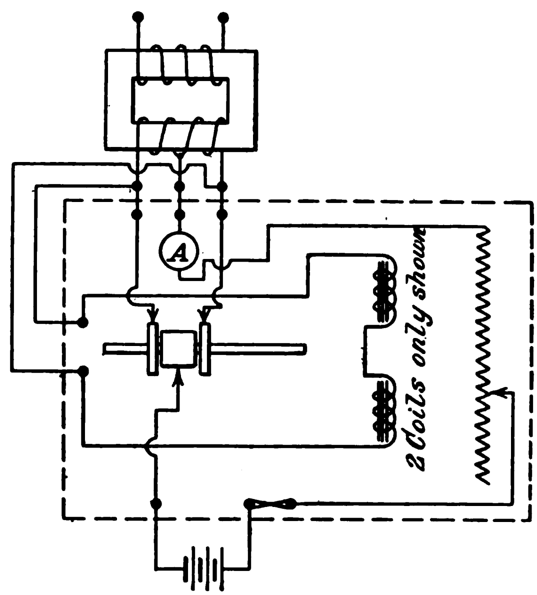


Fig. 5.—Simplified Connections.

the brush on N, then the same result will be obtained.

Now if, instead of the cells, we substitute the output from the rectifier, while it is stationary, then (assuming the handle to be in the correct position and the brush gear and bearings free), on giving the rotor just half a turn it will accelerate, and finally fall into synchronism, accompanied as before by a series of beats, which get fainter, and finally die out. Now, although the system has been made self-starting, we no longer know the polarity, because there is no permanent magnetism in the rotor to decide into which

phase it will fall, so, obviously, this rotor must, in some way, be magnetised.

An addition which has not yet been tried to do this, is to put another high-resistance winding over that already on the rotor, and connect it to two slip rings and their brushes across the accumulator. A high-resistance winding, many turns of fine wire, is sufficient, as very little extra magnetism (of a definite polarity) is required to decide in which phase the motor will start. This coil, when once the rectifier is running, may be switched out of circuit.

The method by which the rectifier works should be quite clear from a consideration of the diagrams. If the accumulator voltage is

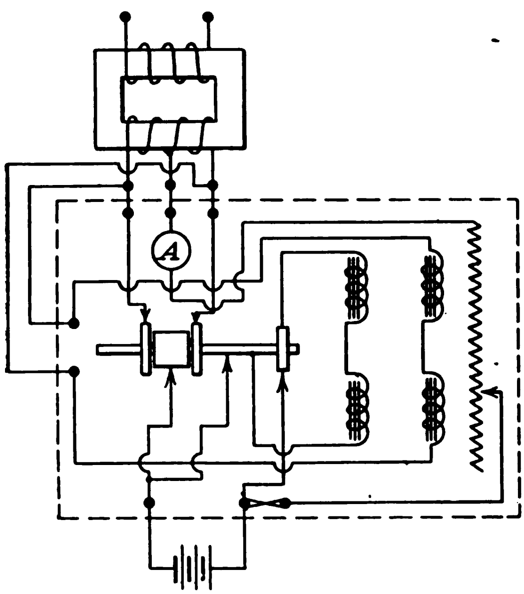


Fig. 6.—A More Elaborate Scheme.

6, and the charging voltage 8, then the field coils can be adjusted till almost no current flows both at make and break (see Fig. 8), and thus sparkless running is obtained. If the charging voltage is in excess of this, then the field coils must be turned till there is no current flowing at break (the sparking at make being negligible).

Rectifiers of this type, with a 1-in. commutator, will deliver, if required, up to 12 amps. when charging a four-volt accumulator with 8 volts.

There are other uses to which such a synchronous motor may be put; if a disc of

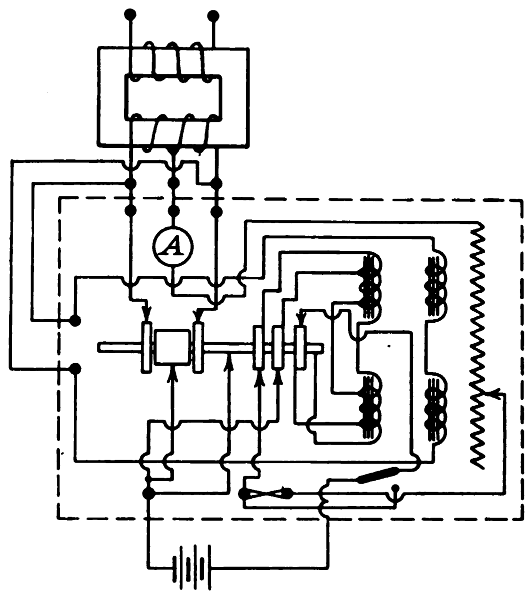


Fig. 7.—Circuital Arrangement of the Complete Accumulator Charging Plant.

wood or ebonite is fixed on the shaft, with a number of contact studs equally spaced around its circumference, and a brush allowed to make contact with it, this may be used as an interruptor for I.C.W. transmission. The chief advantage lies in the fact that it will (assuming the main's periodicity to be constant) always emit a note of constant frequency; further, knowing the main's periodicity, the note can easily be calculated. The system could advantageously be applied to Morse transmission by the difference of note system.

If for the synchronous motor described above, a D.C. motor is substituted, and if D.C. is applied to the two slip rings, then, when the motor is running A.C. will be obtainable from two brushes opposite one another on the commutator. These must be exactly opposite or bad sparking will occur.

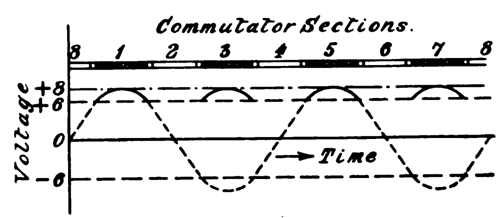


Fig. 8.—The Conditions for Sparkless Running.

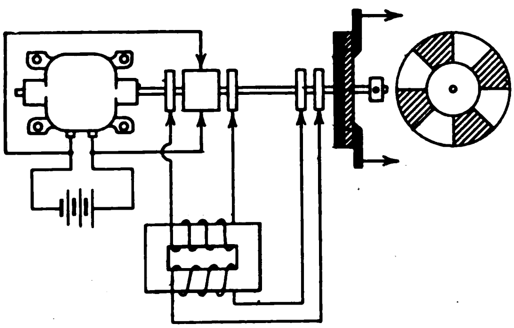


Fig. 9.—Circuit Employing a Synchronous Rectifier to Obtain High Voltage D.C. for a Transmitter.

Finally, this A.C. may be transformed up to a high voltage, suitable for transmitters, and applied to two more slip rings, on the same shaft, which are connected to another commutator. Then pulsating D.C. will be obtained, when the commutator angle is correctly set, from the brushes collecting from it. A large commutator with big ebonite dead sections should be used to prevent flash-over due to the high voltage.

The Mechanics of Components.

By GEORGE GENTRY.

Home-made experimental equipment frequently suffers from faulty mechanical details. In the following notes an expert deals with the principles of good design and sound constructional methods as applied to wireless components

No. 3.—Switch Construction.

FIG. 1 with this instalment shows, in scale section, a type of multiple-contact switch having a fixed stud as a pivot in place of a rotary spindle. Switches like this are much easier to construct on account of the fact that there is no need to fit to the panel any form of bush. The pivot stud is shown to consist of a 1½" length of No. 2 B.A. screwed brass bar, passing through a similar size clearing hole in the ebonite panel. This clearing hole should be drilled by means of a 3-16th" drill in the first place, the resultant hole from which will, if the bar is not under size, probably be a fairly tight fit, mainly because ebonite tends to settle inward after drilling, and may present thereby an under-size hole. It is better not to force the stud through such a hole, but to ease the hole out very slightly by means of a broach. The resultant fit, in any case, of the stud to the hole should show no appreciable play, as if it does so, all the stability of the stud depends upon the pressure of its washers on the ebonite surfaces, which is not a good construction to rely upon. If the experimenter is equipped with suitable screwing tackle (such as No. 2 B.A. stock and die, as well as the corresponding taps), and he is willing and able to do the work, much better studs for the purpose can be made from 3-16th" round brass bar. The difference is that he will still have the same length of stud, but will screw it down from the top to a point about level, or a shade below, the surface of panel; and similarly screw it up from the bottom, in which case the portion of the stud shank in the hole is left plain, a construction much less likely to become unstable. It is advisable to make sure that there is sufficient length of thread up and down beyond the level of the face of the nuts to allow the nuts to take a firm bearing on the washers, otherwise they may seize on the screw before taking their bearing, and, though appearing to be tight, are really not holding the stud enough to prevent it turning in the panel when apparently adjusted somewhat tightly.

Referring to the same figure, it is noted that above the panel is a washer against which bears a standard 2 B.A. nut (*i.e.*, not a lock nut) which is bevelled (or chamfered) on one edge only. Put the chamfer downward, and lock this by a pair of locknuts

bearing on a washer on the underside of panel. The actual locking of the stud is done between the large nut at top and the upper locknut at bottom, the pur ose of the washers being to extend the bearing surface on the ebonite, and to prevent the nuts turning on the softer material. The lower locknut can be used to bind the lead

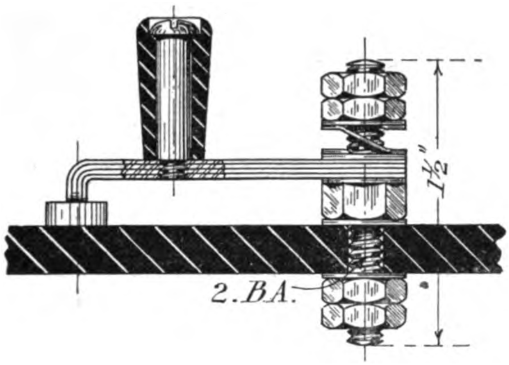


Fig. 1.

from the switch, or the latter may be sweated to the point of the stud. In either case the second locknut should be used.

Above the switch arm is fitted first a washer, next a copper spring washer, followed by another washer, the whole being bound down by a pair of locknuts. These should give a firm adjustment to the spring, so that the rubbing contact of the arm is maintained with just sufficient resistance to turning to keep the switch arm on the requisite stud at its working end. The upper nuts should be locked to each other quite firmly to ensure that the friction of the arm in turning neither releases nor tightens them, as either of these contingencies may throw the switch out of action.

The arm shown is the standard pattern laminated copper switch-arm sold by all the wireless dealers. It consists of four laminations, each about 1-32nd" thick, and connected by a rivet or clip at the position shown for the handle. The idea as drawn, is to remove the rivet, and keeping the laminations carefully clipped together in their correct relative positions, to drill a No. 26 hole (*i.e.*, No. 26 drill is the tapping size for 2 B.A.) and tap it 2 B.A. To this is fitted a round-headed, plain-shanked set-screw which carries a bored ebonite handle. Handles of the kind shown, which for preference and easy working should be fitted on the screw spindle capable of revolving, are made and sold in the general electrical trade (not necessarily the wireless trade). They are to be procured in ebonite, moulded ebonite, "ebonestos," "erinoid" and similar insulating materials all quite suitable for switch handles. The general fitting up and arrangement of the switch has already been dealt with in the May issue of EXPERIMENTAL WIRELESS. This form of arm, while requiring, when off the contact studs, to spring down 1-16th", just like the single strip arm, requires to be fitted, not only so that it bears on the stud evenly across, but also so that each lamination springs down and also bears evenly across. The object of this is to give the switch the largest stud contact of which such an arm is capable.

If current-carrying capacity is a point to be considered, a good way to fit these laminated arms to decrease contact-resistance is as shown in Fig. 2. Instead of having the arm bent down at right angles, it should be set down approaching the stud, either with a curve or straight down at an angle of 45°, or less, to the horizontal. Then, if it be filed flat at an angle to the curve, on a plane parallel with the arm itself, it presents about its maximum contact-surface to the stud. Rather more care in this case is required to ensure that each lamination has a spring effect on its own account, and therefore bears

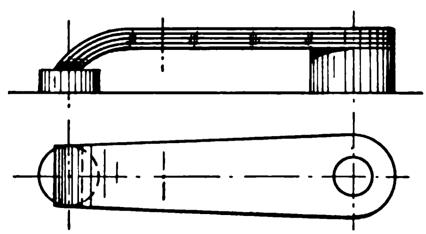


Fig. 2.

well on the stud and also along the whole of its bottom edge length. It is usual to note that each lamination makes a distinct polished line on each and every stud of the switch as evidence that the contact resistance is reduced to the minimum.

Fig. 3 shows a form of solid pivot stud which is shouldered and fitted with a solid slotted arm, shown in the views (Fig. 4)

below the pivot stud. The stud may be either made solid, turned from a piece of ½" round brass, or built up as follows:—The fixed collar on the panel is 7-16th" diameter by ¼" thick, and the journal above (*i.e.*, a journal is a portion of a stud or shaft which runs in a bearing, or upon which, in this case, the switch arm turns) is ¼" diameter by 3-16th" long. Thus the switch-arm matches the large collar in diameter of boss, and is holed ¼" to run on the journal. There is a shoulder above the journal so that first a washer can be put on followed by a knurled nut. The nut and washer are screwed down tightly to the shoulder, in which position they do not confine the switch-arm, which is made free to revolve on the journal. The arm is of solid brass and has a fine saw-cut made up its horizontal centre and parallel with the base of the boss. By opening this saw-slot out a little spring tension is put on the swivel end of arm, so that, with the washer and nut bearing on it, it has a certain frictional resistance to turning which makes it smooth in action and free from end play. To build up the stud, procure a 1½" length of No. 2 B.A. screwed bar and a tapped collar. These collars have been purchased among regular wireless fitments. Tin the screw where the collar is to be and screw it on together with some flux while the screw is hot. It will then solder on tightly if held in a flame. The journal portion can be made from a 3-16th" No. 2 B.A. spacing washer as used in condenser building, and this need not be soldered on as it is held tightly by the nut and washer. The remainder of the switch construction involves the fitting of a handle similar to that shown in Fig. 1, and a small spoon-shaped spring for stud contact. The writer, in making a switch like this, made the spoon-shaped spring first by cutting out a small circle or disc of silver sheet having a tang on one side. This disc was dished by laying it on a block of lead and giving it a blow with a rounded punch. After this a strip of light

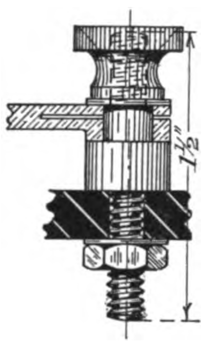


Fig. 3.

clock spring about 3-16th" wide was soldered to the silver tang. The spring was then softened over the area where the screws are, in order to drill it for the two No. 9 B.A. set screws by which it is screwed to the arm. Care was taken to solder it very rapidly to the silver in order not to take the temper out of the main portion of the spring, as it depends on its springy character to maintain a good rubbing contact on the studs. The leads to the fixed pivot stud on the underside of panel can be attached as described for Fig. 1. This type of switch is very smooth in working, and, if correctly made, is particularly adaptable for working over a complete circle of studs, and if each stud be faced by a disc of silver or German silver sweated on, there is very little trouble on the score of bad contact. The studs, of course, must be put sufficiently close together to allow of the spoon-shaped end sliding

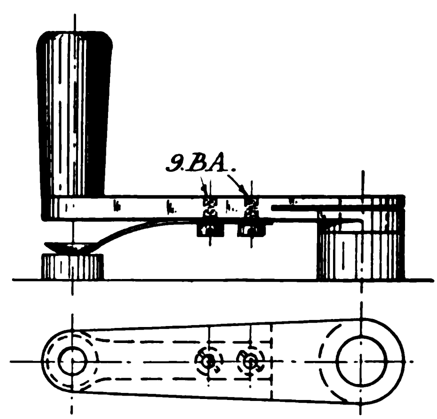


Fig. 4.

from one to the other without any marked jump in the change. There is more work, however, in making this switch than in those previously described.

Fig. 5 shows a simple method of adding to the contact area of a single spring strip switch arm. A second spring of lighter material, such as German silver, is riveted to the underside of the arm, and is brought

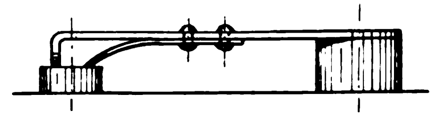


Fig. 5.

forward by an easy bend on to the back of the face of the stud. The front contact of the main arm, instead of being on the centre of the stud, is set forward. This is a simple construction and will work well if the second spring is made much lighter so that it does not affect the contact of the main arm.

Fig. 6 shows a method of balancing a switch arm which can be applied to both a single strip or laminated arm. A fixed pivot stud is used, but it is not of necessity in the circuit, the arm being continued beyond it on the side remote from the multiple studs, set down, and formed to

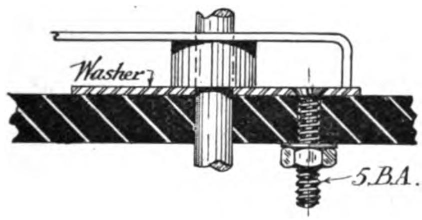


Fig. 6.

make a rubbing contact with a thin washer, preferably of copper, held under the shoulder of the pivot stud. The washer may be held from revolving by one or more countersunk-head No. 5 B.A. set-screws carrying a nut and washer on the underside of panel. One of the latter forms the lead-out, which need not now be taken from the pivot stud. Quite a fair degree of pressure can be put on the studs by the arm, and by reaction the same pressure is carried over to the other end and ensures a similar pressure on the washer. Any inadequate contact with the pivot stud does not matter, as this stud is not used to convey current to the leads either way. The only two rubbing contacts are that between the arm and studs and arm and washer, and, as explained above, the more effective the pressure on the one the more it is on the other. It will be realised that this method of balancing a switch arm can be, if anything, more effectively applied to rotary spindle switches than to those with fixed pivot studs; but, in the latter case, although only part of a fixed stud is shown, this can be of a similar form to that shown in Fig. 1. The idea does not lend itself readily for application to the type shown in Fig. 3.

Fig. 7 is a section of the fixed studs of the double-pole collector switch, which was illustrated by a photograph described on page 484 of this volume of EXPERIMENTAL WIRELESS. Without going into much detail it may be as well to state that the switch is used to collect in series three out of four 2-volt accumulators, and can be set to vary the series in sequence, 1, 2, 3; 2, 3, 4; 3, 4, 1 and 4, 1, 2. One arm is always on the positive and the other on the negative, and the arms being set at a fixed distance, and maintained so by an ebonite connector, only 6 volts, neither more nor less, can be collected. If the whole battery were mounted in complete series it would, of course, be permanently short-circuited; therefore the series connection is broken between cells 2 and 3, and also between 4 and 1. The two-way turn button switch, shown in detail, Fig. 8, connects either of these two junctions, but, being a cross-over switch, it cannot be set to connect both junctions at once. If the double-pole switch be set on either the series 1, 2, 3 or 2, 3, 4, then the cross-over must be set to the left, but if it be upon either 3, 4, 1 or 4, 1, 2 the junction must be made to the right. Should these not agree, for instance, if the series 3, 4, 1 be set with the junction made to the left, the only ill effect is that cell No. 2 is put alone into circuit the reverse way, which is immediately noticed and corrected. In most straight-forward valve circuits the H.T. negative goes to the L.T. positive, whereas, in some reflex circuits, the H.T. negative goes to the L.T. negative. This switch is arranged so that all the leads-in from batteries are on the underside, hence a terminal is put at the bottom of each fixed stud in order to attach the H.T. negative. There is an independent terminal (not seen in the photo) for the attachment on the underside of the H.T. positive and to lead off on the upper side. All leads-out to the valves, etc., are made at the top, therefore the

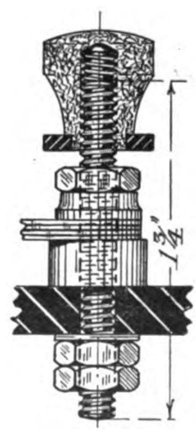


Fig. 7.

fixed studs have to be fitted with terminals at their tops also. Referring to Fig. 7, the stud consists of a $1\frac{3}{4}''$ length of 2 B.A. screwed bar, to which is sweated a $\frac{1}{2}'' \times \frac{1}{4}''$ tapped collar, with its under face 11-16th" up from the bottom. This is lock-nutted to a washer on the underside of panel tightly, the second lock-nut being for attachment of a H.T. lead. Surmounting the collar, and making rubbing contact to it, is the four laminated copper switch-arm

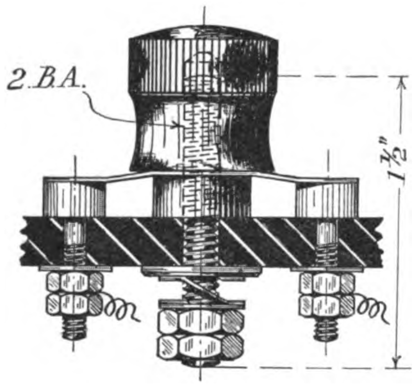


Fig. 8.

holed 2 B.A. clear size. The tension on the arm is effected by a second tapped collar (the base of a 2 B.A. terminal) locked to a lock-nut above. The collar is actually filed flat on each side to take a spanner. The top terminals are made from a pair of knurled "Erinoid" handles, made and sold in the wireless trade attached to H.T. battery plugs. The red one is on the positive stud, and the black on the negative. Both were removed from their pegs, chucked bottom outward in the lathe running true, and drilled up No. 26 drill, or 2 B.A. tapping and tapped that size in a blind hole (*i.e.*, not through the top). They were also, in the same setting, turned down to a shoulder on the outside and fitted with a 9-16th" diameter by 3-22nd" thick ebonite washer, holed 9-32nd", which was tapped on tightly. The washer acts as a hood to protect the joint from accidental short circuiting with the second stud, about $2\frac{1}{2}''$ from it. All contacts are made under these insulating terminals. It would be better, however, to put a $\frac{1}{2}''$ diameter by 3-16th" holed brass washer on the top of the nut, as the latter does not offer a very good terminal face for the wires.

The turn-button switch (Fig. 8) consists of a large black tapped "Erinoid" knurled knob, locked tightly down on to a tapped brass collar sweated to a $1\frac{1}{2}''$ length of 2B.A. screwed rod. Between it and the collar is clipped tightly a 1-32nd" thick German silver balanced arm riding upon studs at both ends. It is spring strip, and is set down in the manner shown to bed evenly on the stud faces. The spindle is not a terminal, but is lock-nutted with plain and spring washers between on the underside of panel. The leads are on the studs only. The upper washer on the ebonite is extra large and thick and does not turn with the spindle. The spring washer should be oiled slightly to effect a running joint against this washer. No bush is needed, as the series switches are only seldom operated. The cross-over movement is to 90°, and there is on both sides a black fibre rider screwed to the panel not touching any of the studs. The stops on either side are fibre blocks similarly screwed to the panel. This is an instance of a balanced arm rotary spindle switch.

Fig. 9 shows the method of fitting fibre riders between studs of the main collector

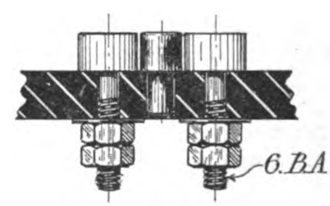


Fig. 9.

switch. The riders are shouldered down and driven into holes in the ebonite midway between studs, but not touching them. The top is a shade above the stud tops, and is rounded on the edges, and as the contact passes from one to the other by its rounded edge it rides up over the fibre and prevents short circuiting neighbouring studs of the collector.

Radio Station G5RZ.

By A. G. WOOD.

SO much has been said about successful trans-Atlantic transmitters that perhaps a few words about unsuccessful ones might be of interest. Possibly the more serious experimenter may be annoyed at the levity with which the subject is treated, but unless the humorous side of a breakdown at 3 a.m. on a cold morning is seen the results to the mental systems of the operators involved are liable to be extremely detrimental.

Somewhere about April 1—a suitable date for its inception—we decided to combine for the next autumn trans-Atlantic tests. It was realised that the strain of continual sitting up, combined with the drain on one's finances for the replacement of transmitting valves, were likely to prove too much for one person.

The details were finally worked out at Shoreham during an early holiday while gathering inspiration listening to 2LO on a single-valve Armstrong. On completion of the holidays there was a temporary hold-up experienced owing to financial straits. This, however, rectified itself towards the end of July, when a preliminary application for a high-power permit was passed to the G.P.O. and inquiries instigated regarding suitable valves for the attempt. Both eventually materialised, and preliminary experiments were started to determine as far as possible on low power the most suitable type of circuit to work with the aerial on high power. Alternating current from the company's mains was available at a pressure of 220 volts 50 cycles, and it was at first hoped to rectify this and transmit on pure C.W.

Accordingly various methods of rectification were discussed, and a start was made with the synchronous rectifier. The first attempts were extremely crude, consisting of a magneto fed with 4 volts A.C. on the low-tension winding and run into synchronism by a small D.C. motor. The only available motor was rather old-fashioned, taking about 6 amperes at 10 volts on no load, and even with a big step-up gearing the required synchronous speed of 3,000 r.p.m. was scarcely obtainable.

Mounted on the end of the magneto shaft was a metallic pointer revolving between two fixed electrodes. At a pressure of 2,500 volts the arc produced rendered external lighting unnecessary, and, although looking extremely businesslike, was rather inefficient from the direct-current point of view. The construction of a correct commutator was then undertaken; this, while proving very efficient, was found to have a short life, and it was estimated that to transmit test schedules for one week the demand of new commutators would exceed

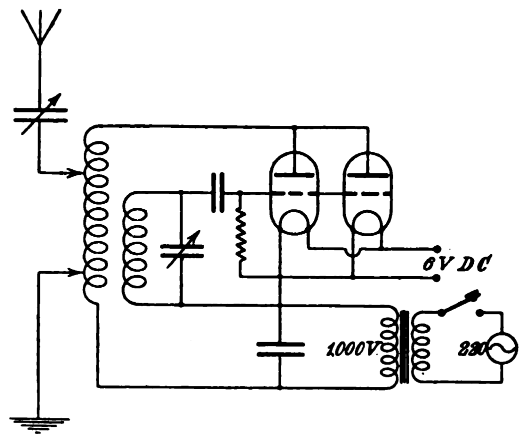


Fig. 1.

the probable supply even if mass production was resorted to.

Attempts were next made to obtain a high-tension direct-current generator of suitable wattage. This, however, proved unsuccessful. (The only person whom we knew possessed one had seen our earlier attempts at "Sink. Rectification," and was out every time we called!)

A strong discussion then ensued regarding unrectified A.C., and it was decided, after test, that 50 cycles was too low a note to be read at long distances through heavy QRM.

The tests that this conclusion was based

on were carried out with ex-W.D. "B" valves working at about 1,000 volts anode potential. It was found at this stage that the expenditure curve of the station began to rise in rather a surprising manner. At this anode voltage heavy mechanical vibration was experienced within the valves; and, owing to the use of only one half-cycle, serious low-frequency surges were produced, necessitating the liberal introduction of chokes. Excessive heating was also noticed. A radiation in the neighbourhood of 1 ampere was obtained, and on August 18 tests with Danish 7ZM were undertaken, but, owing to local jamming on either side, communication was not established, although by a later

of the high-tension input, the latter being about 500 cycles.

From the very first this circuit proved a success, radiation increasing at once with a decrease in input, the whole being much more stable and controllable and the life of the valves being slightly longer. Surges were practically eliminated with the exception of those in the grid circuit, and after the operator had noticed one or two of these by touching the brass part of the key whilst transmitting a relay was constructed.

Except when absolutely impossible, these tests were carried out on an artificial aerial constructed to approximate to the outside aerial system.

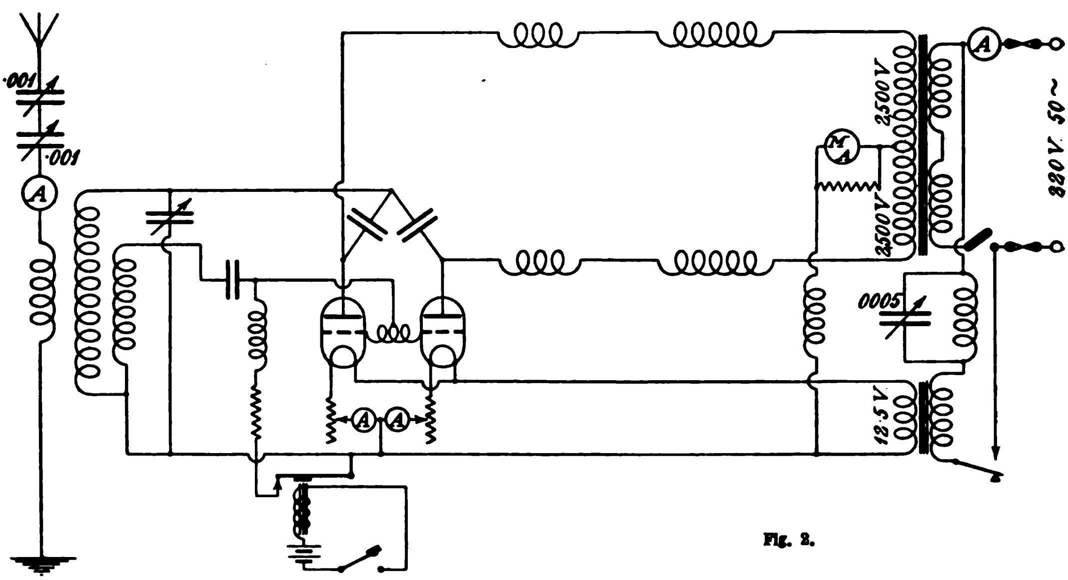


Fig. 2.

report it would appear that Denmark heard our signals at a strength of approximately R6. The distance was 620 miles. This 50-cycle note spread rather badly, and was apt to prove unpopular with neighbouring amateurs.

It was next decided to use some form of self-rectification circuit, and, procuring a fresh stock of "B" valves, operations were recommenced on August 22, employing the circuit shown in Fig. 2. This circuit is similar to that employed by WNP, the *Bodowin* exploration ship which is at present "iced in" near the North Pole, the only real difference being the frequency

During these tests intermittent reception of American signals was going on, resulting in average week-end logs of five stations. Note was made of the more persistently-received stations in order to endeavour to communicate later on in the year. It is of interest to note that at the end of one such sittings at about 6.15 a.m. the aerial gently subsided from no apparent cause. This has always remained a mystery, as there was no wind blowing at the time.

Looking back on our logs, it was decided that the standard of reception was not sufficiently reliable, although in the light of future experience this was probably more

due to weather conditions than to the receiver.

However, some thorough groundwork was put in on the receiver, twisted wires becoming soldered joints and stray capacities being reduced to a minimum, which resulted in better efficiency all round.

From then on until November 15 alternate week-ends were spent in listening-in and

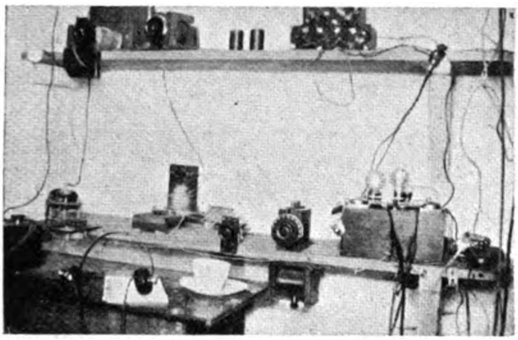


Fig. 3.

re-erecting the aerial, which, owing to an eight-wire twin cage system and the small available base line for guys, showed a disconcerting tendency to subside during any unusually high winds. Finally, a fairly sound job was made of it, resulting in an aerial about 70 ft. high one end and 65 ft. the other.

On November 15 the two 0/250C Mullard valves arrived, and with the G.P.O. permit already obtained serious work was started. The station was completely ready for the new valves, and as it remained practically constant throughout the tests some idea of the general lay-out may be obtained from the photographs.

Fig. 3 shows a general view of the three-valve receiver. This consisted of one H.F. valve rectifier and one L.F., with provision for two L.F. (Note the cup of tea, which was heartily appreciated at the time that these photos were taken—between 3 a.m. and 5 a.m.)

Fig. 4 shows the transmitting helices, the aerial series condenser (in the jam pot), below the helices the two valves, and above the two hot-wire aerial ammeters in parallel. On the extreme right can just be seen the H.T. transformers (shown elsewhere). The filament transformer can be seen in the lower left-hand corner. This was tested when completed on overload of 72 amperes at 12½ volts, and stood this without becoming *very* warm for some considerable time!

Fig. 5 gives another view of the receiver with two operators listening in. (Yet another cup of tea is in evidence here!)

Fig. 6 gives a clearer view of the H.T. transformers. These were connected in series parallel (for centre tap), and gave 2,500-3,000 volts when working. Note the cut-out switch, the series resistance in the input lead and the electro-static voltmeter. The circular object seen in the middle of the photo is one of the low-frequency "surge" chokes.

Fig. 7 shows another view of the transmitter. The coil of lead-covered cable on the extreme right top is the stopping condensers described elsewhere in this article. (Note operator's hat and coat hanging on the door!)

Fig. 8 is a more general view of transmitter, valves, etc.

Almost from the first troubles were experienced in balancing the valves, and it

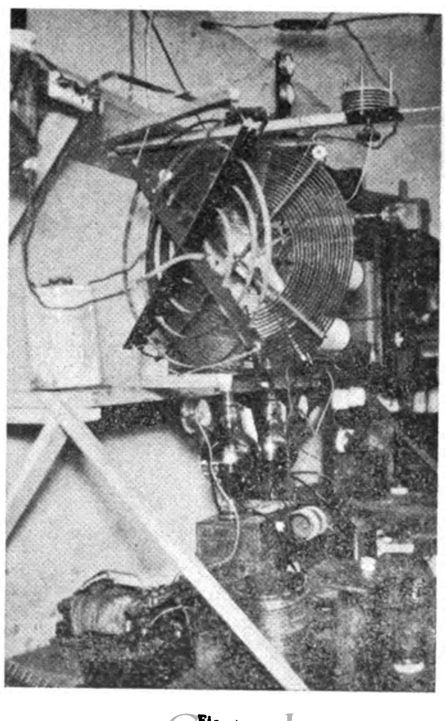


Fig. [illegible]

Fig. 5.

was found that one possessed widely different characteristics from the other. Upon communication with the makers they readily agreed to change them, and spent much time and trouble to procure us an exactly similar pair.

In Fig. 7 can be seen the hastily improvised H.T. condenser after a breakdown one morning. This consisted of a short length of twin lead-covered wire, the capacity of each core to lead forming one condenser and the lead the centre point. This was rushed in at five minutes notice and was used for two or three nights whilst fresh condensers were being constructed. Towards the end it was repeatedly breaking down, so that the operator on duty was compelled to keep one hand on his key and the other on the main switch (see Fig. 9). After each breakdown the damaged portion was cut away—if not already blown out—a splice was made and the cable reconnected. Owing to frequent practice the time necessary for this operation was reduced to two minutes, the cable eventually being dissected into 6-in. lengths !

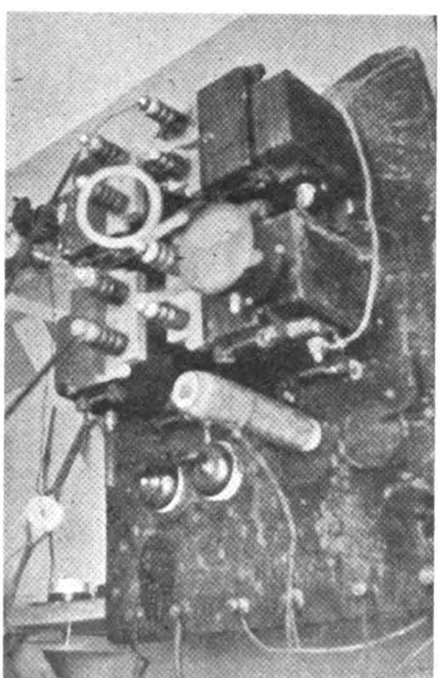


Fig. 6.

The only satisfactory grid leak proved to be a liquid one. Bicarbonate of soda was added to the water to reduce it to the necessary resistance, but on one occasion, in the early hours of the morning when no soda was available, cold tea proved an efficient substitute !

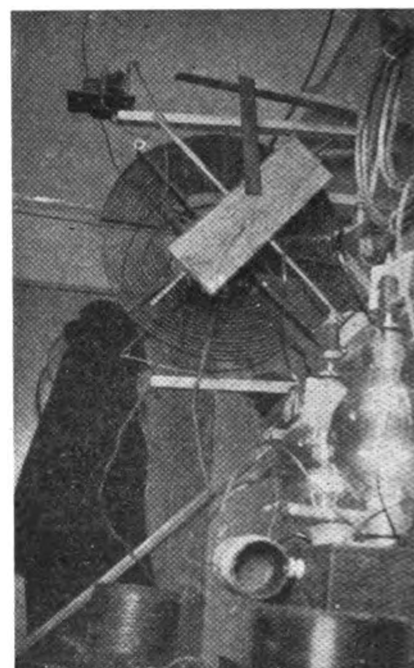


Fig. 7.

The value of the grid leak was found to be critical, either side of the correct value producing severe surges. These were finally eliminated by a large grid choke. That this effectively worked was repeatedly shown by the large voltage rises across it being sufficient to break down ¼ in. gap in air.

Some various tuning phenomena were experienced. On one setting of the transmitter an increase of the series aerial condenser actually resulted in a decrease in wave-length, and the two aerial condensers that were employed in series both showed a tendency to spark over, while a double-spaced ·0003 microfarad across the anode coil would at times maintain a small arc.

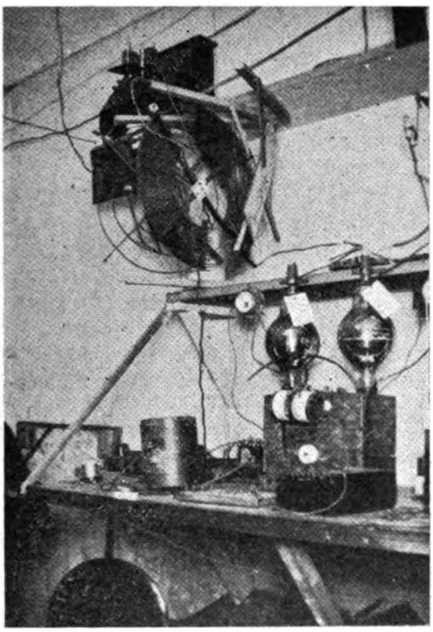


Fig. 8.

Another curious fact was revealed by a long-distance report during some adjustments that at times our signals were unintelligible owing to the fact that there were two distinct wave-lengths on each half-cycle; thus a dot would be transmitted on one, whilst the following symbol occurring on the opposite half-cycle would be on a different wave-length. Owing to their closeness this was not noticeable in the wave-meter, nor for that matter even at a distance of 200 miles, but with the increase in distance and the resultant reduction in signal strength only one wave-length at a time could be tuned in. At the conclusion of the R.S.G.B. tests, and in the absence of definite reports from the other side, it was decided to drop to a wave-length lower than 160 metres, as successful reception both of KDKA and many American amateurs had been carried on for some time with complete absence of QSS and QRM. No trouble was experienced in getting the transmitter down to this wave-length with the exception of the hot-wire ammeters proving useless owing to the effect of the capacity of the terminals to the case at this high frequency. Other methods to measure the radiation were therefore adopted. These consisted of a single turn of wire looped over the aerial lead-in and at least 3 ins. clear from it. This loop was connected in series with a permanently set crystal and a Weston galvanometer heavily shunted. The latter was calibrated against the hot-wire ammeters on the longer wave-lengths and the calibration assumed constant for the shorter wave-lengths. While the reading would not be very accurate, this at any rate provided a comparison for different adjustments.

Although apparently unsuccessful in our endeavours, much interesting experience has been gained from the tests, and we look forward to better luck next year. In conclusion we would like to tender our best thanks to the Mullard Radio Valve Co., Ltd., for their kindness in the loan of the valves and the great trouble they took to provide two that were exactly matched.

The valves worked admirably throughout the tests, and gave us no cause for any anxiety, comfortably handling their full rated load.

Some Experiments with Electrolytic Rectifiers at High Periodicities.

Little is known about the action of the electrolytic valve except on the usual commercial frequencies. The following notes may be of interest to experimenters who desire to utilise sources of higher periodicity for H.T. supply.

THE opinion is prevalent that the aluminium rectifier will not work with any practical degree of efficiency at frequencies much in excess of 100 cycles per second. This is either definitely stated or implied in most of the available literature on the subject, and the present writer is also guilty of making such an assumption in an earlier issue of this journal.* Indeed, if an ordinary rectifier designed for 50 cycles is connected straight to a 500-cycle supply, it

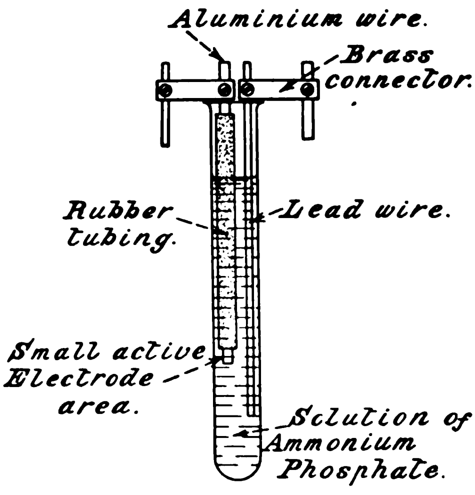


Fig. 1.—Details of a Rectifier Cell Designed to Rectify Small Currents at 500 Cycles.

is found in most cases to act as a short circuit, taking a large current from the supply and yielding no appreciable rectified output. Such hasty tests have probably been responsible in some degree for the existing conceptions of the frequency limits of the electrolytic valve. We have been making some tests lately, however, in the EXPERIMENTAL WIRELESS Laboratory over a wide range of frequencies, and have obtained some interesting and encouraging results.

That the efficiency of an electrolytic rectifier must fall off as the frequency is raised is, of necessity, the case, for at least two reasons. In the first place, given an aluminium electrode of fixed dimensions, a certain amount of work must be done in alternately forming and removing the insulating film on the aluminium surface; this represents a certain amount of electrolytic action determined by the thickness of the film and the area to be covered, and the electrical energy used in effecting this electrolysis constitutes an unavoidable loss. The more times per second the film has to be formed and destroyed, the greater will be this loss. It will, in fact, be directly proportional to the frequency if other things are kept constant. We have also to consider the fact that the film must take a certain time to form during one half of each cycle sufficiently to stop inverse currents and clear away in the other half of each cycle sufficiently not to constitute an undue resistance. The time available for these changes to take place obviously decreases as the frequency is raised, so that with comparatively high frequencies, such as 500 cycles, a large proportion of leakage current to rectified output is to be expected.

A third and rather different effect which comes into play is the condenser action of an aluminium electrode when polarised. The insulating film which forms on an aluminium electrode when it is made positive with respect to the solution is so thin that the aluminium and surrounding solution act as a condenser of quite large capacity. With an area of only a square inch or so of aluminium, a capacity of over a microfarad may quite easily be obtained. The effect of this capacity in even a 50-cycle rectifier is quite appreciable; it has a marked effect on the power factor of

* Vol. I, No. 3.

the A.C. input circuit, and gives rise to capacity currents through the rectifier cell, which are distinct from and additional to any leakage or polarising current. Since the reactance of a condenser is given by $\frac{1}{2\pi f C}$, where f is the frequency and C the capacity, it follows that an aluminium electrode of given size has a much greater capacity by-pass effect on higher frequencies. At frequencies of about 500 cycles, this capacity effect plays an important part, while at 10,000 cycles it is one of the most important problems to be dealt with. Owing to resonance phenomena between the capacity of the rectifier and the inductance of the H.T. transformer windings, all sorts of unexpected things may occur.

A few simple experiments were made to examine the rectifying action of an aluminium electrode in a solution of ammonium phosphate at frequencies of 500 and 10,000 respectively. The 500-cycle supply was derived from a small Newton alternator, while the 10,000 supply was generated by a low-power laboratory arc working off the 200-volt D.C. mains. From the considerations stated above, it was evident that the surface of immersed aluminium must be kept very small in comparison with the current to be handled if any appreciable fraction of the total power expended is going to appear as useful rectified output. When, for instance, the input terminals of the 50-cycle H.T. rectifier shown in the December issue of EXPERIMENTAL WIRELESS (Vol. 1, No. 3, p. 155) were connected across the 500-cycle supply transformed up to 800 volts, a heavy load on the supply resulted, but practically no D.C. could be drawn from the output terminals, although the rectifier was in excellent working condition for 50 cycles. Next, some special cells were made up, having aluminium electrodes consisting of strip only, three millimetres wide, and dipping a centimetre below the surface of the electrolyte. Quite an appreciable amount of rectification took place, and for an A.C. input to the rectifier of 100 milliamperes, about 50 milliamperes of D.C. output was obtained.

The arrangement of having small aluminium electrodes dipping just below the surface of the solution has, however, practical disadvantages. In the first place, owing to the high current density, there is a good deal of local heating up of the electrolyte immediately around the electrode, and as the heated liquid always rises to the surface, the aluminium is surrounded by hot liquid, where it enters and the rectifying action is destroyed Once rectification ceases, the heating effect becomes worse ; in fact, the heating up of a rectifier is cumulative. Another disadvantage of the local heating is that the aluminium is rapidly corroded where it enters the solution. A third disadvantage, and an important one, is that owing to surface tension, the solution creeps up the electrode to a height considerably above the surface level, thus increasing

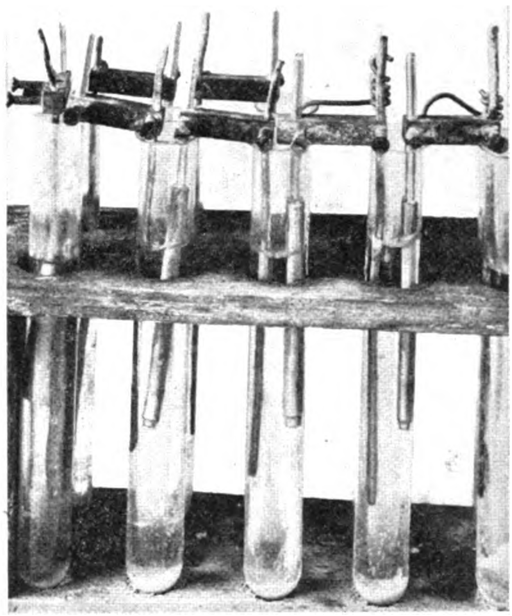


Fig. 2.—Close View of a few Cells of the 500 Cycle Rectifier. Note the Small Aluminium Electrode Area.

the effective electrode area, and probably making it too large.

Next an attempt was made to construct a high-tension rectifier, making use of the experience already gained, which would be capable of supplying about 30 milliamps. of D.C. at a few hundred volts to the anode of a small transmitting valve.

The following points had to be complied with :

(1) The smallest possible surface of alu-

minium in contact with the solution consistent with sufficient D.C. output.

(2) No aluminium in contact with the solution at the surface.

(3) The active part of the aluminium to be sufficiently low down in the solution to be kept cool by convection.

Accordingly, a bank of cells was made up, having electrodes as in Fig. 1. The aluminium electrodes were straight lengths of No. 12 gauge aluminium wire sheathed with rubber tubing, such as is used in bicycle tyre valves. Owing to the necessity of the tubing being a tight fit, some difficulty was at first experienced in drawing it on to the aluminium wire without damaging the tubing. This difficulty was overcome by wetting the lengths of rubber tubing with paraffin oil just before putting them on to the aluminium ; this made them go on quite easily. The rubber tubing must extend from at least 1·5 centimetres above the surface of the solution to within three or four millimetres of the lower end of the aluminium wire, thus confining the active portion of the electrode to an area of about 0·2 sq. cm. below the surface of the solution. The other electrode, shown in Fig. 1, is a piece of thick lead wire. A solution of ammonium phosphate was used as electrolyte during the experiments. A close-up photograph of one cell is shown in Fig. 2, and the general assembly of 24 cells is shown in Fig. 3. The usual Gratz or bridge connections were used, there being four groups of six cells, giving full-cycle rectification. The rectifier was only designed to give about 20 watts maximum output.

This rectifier was tested on alternating voltages up to 400 volts. It was first formed upon a 50-cycle supply to make sure that it was at least in good working condition for this frequency, and then the 500-cycle input was applied from a step-up transformer specially designed for this frequency. With an applied voltage of 300 R.M.S., results were quite encouraging. While no D.C. load was being taken from the output, the load on the input was about 5 watts, but when the D.C. output was short-circuited, the load on the input went up to about 30 watts. This does not, of course, imply a rectification efficiency of 75 per cent., or anything like it, but it does show that the rectifier was quite appreciably efficient on 500 cycles. In spite of what might be considered the absurdly small electrode area of the aluminium, the rectifier would pass 100 milliamps. quite readily on about 400 volts, and the indications were that small electrodes do not occasion such large resistance losses as would at first be expected. The polarizing or "no-load" currents were undoubtedly greater on 500 cycles than on 50 cycles. Also, when, say, a valve oscillator was being applied from the D.C. output, the voltage drop across the rectifier itself was greater on 500 cycles. Nevertheless, we did

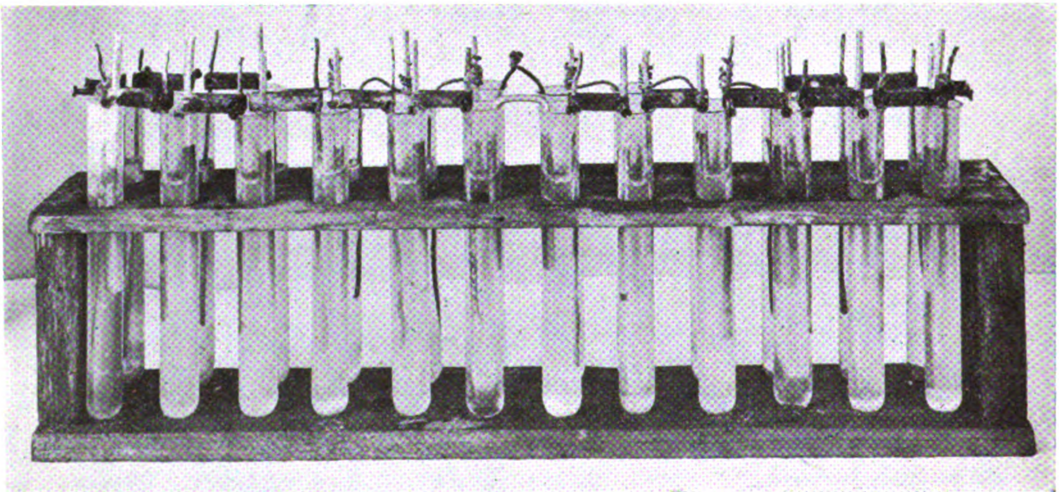


Fig. 3.—General View of Rectifier.

supply a valve oscillator quite satisfactorily, and, needless to say, the smoothing proved very easy at this periodicity. With two 1 mf. condensers and a small iron-cored choke, there was no trace of hum in the C.W. produced; undoubtedly the smoothing could have been effected with much smaller condensers.

The same rectifier was next tested on the 10,000 cycle supply—more as a practical joke than practical politics. The arc circuits are shown in Fig. 4. The H.T. transformer was air-cored, the primary forming the inductance in the arc oscillatory circuit. We were rather surprised to find that rectification most decidedly took place with a certain rather low efficiency, which might conceivably find certain practical applications. With an alternating input of 100 milliamps., a D.C. output of 20-30 milliamps. was easily obtained, but at what pressure this was delivered was not ascertained accurately. The arrangements for supplying the 10,000 cycle current were very rough and ready, and conditions were such as not to permit the usual simple calculation of voltage from the transformer ratio. Under certain circumstances it was even found that the load on the input went down when the D.C. output was short-circuited; this is one of the unexpected things previously referred to which arise from the resonance effects, due to the condenser action of the rectifier. The rectifier had been built more with the idea of rectifying 500 cycles than 10,000 cycles, and the fact that there was any rectification at all on the latter frequency is worthy of note. Further experiments with different electrolytes and various designs of electrodes might enable a better rectifier to be obtained for these high frequencies.

A further experiment was made on a frequency of 1,000,000 cycles (300 metres wave-length). One cell constructed as in Fig. 1 was connected in series with a D.C. milliammeter, and an inductance containing one or two turns of wire. This inductance was tightly coupled to a closed-circuit valve oscillator generating about 30 watts on 300 metres wave-length. A D.C. current of one or two milliamperes was registered by the milliammeter in the rectifier circuit, showing that even alternating currents of a million periods are rectified to a slight extent by an electrolytic rectifier. The efficiency is so low that this is now only of academic interest.

Possibly the electrolytic rectifier, even if not an efficient proposition for power work on medium high frequencies, might find a useful application in recording work.

Conclusions.

(1) The electrolytic rectifier is capable of rectifying to a certain extent from the lowest frequencies to a frequency of a million cycles.

(2) The efficiency falls off as the frequency is raised. Useful efficiencies may be obtained up to 500 cycles.

(3) The higher the frequency, the greater must be the working current density at the aluminium electrode. For 500 cycles, this is of the order of 0·25 amps. per sq. cm.

(4) At 500 cycles allow 50-80 volts (R.M.S.) per cell.

The experiments referred to are only of a preliminary nature. We hope to give further details when available.

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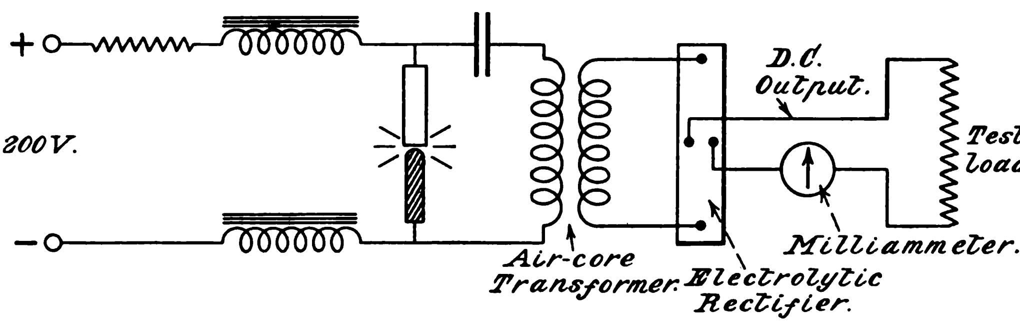


Fig. 4.—Arrangement of Arc Generator for Testing Rectifier on 10,000 Cycles.

Amateur Transmission.

2KW on the Amateur's Position.

The news that amateur communication with countries other than our own is banned has come as a severe shock to the transmitting fraternity in this part of the country. Although we agree that a tightening up of the regulations is, in some cases, necessary, we are of the distinct opinion that the wholesale curtailment is simply the thin end of the wedge. Amateurs have, for a long time, enjoyed comparative freedom from attentions of the Post Office authorities ; now the shock is all the more resented, and it is as sudden as it is complete.

In the past, transmitting permits have been granted to applicants who should not have been in possession of a transmitting permit at all. Now we find that, owing to the tightening up of regulations governing the issue of such permits, many experimenters of undoubted ability are the unhappy sufferers. They are paying for the sins of others. Thus, many are debarred from the experimental field just because they did not apply for a permit sooner ; they may have waited until they considered themselves honestly fit and proper persons to hold a permit. The writer personally knows one of these unfortunates who, after holding the P.M.G. 1st Class Certificate and operating different sets up to five kilowatts power during the war, has been refused a permit for a ten watt set. He has designed a transmitter which, with 0·1 ampere in the aerial, has been heard 1,000 miles away over land. Although this amateur possesses the necessary knowledge in designing, working and operating sets, he is refused the permit, whilst his neighbour is allowed to grind out misused gramophone records by the hour, to the discomfort and distraction of all serious men.

So little is known of the theory of the propagation of wireless waves over the surface of the earth that any quantitative work that can be done by private experimenters would be of the utmost scientific value. Before it is possible for a private individual to carry out such investigation, he must first of all spend some considerable time in getting together the necessary apparatus. He must first set up his gear, and if his spare time is limited, it will be quite a respectable time before he is ready to test the arrangement. When all is ready it will very often be necessary to test the apparatus over a long period ; for if the range to be covered is great, then the gear will have to be made as efficient as possible. All this preliminary work will take time. It will also be necessary for the experimenter to obtain the co-operation of other men in different countries, and the only effective way for him to obtain this vital assistance is by working with them "over the air." Learning their little peculiarities, and gradually finding out that they are, perhaps, interested in the same line of research as he is himself, tests may be fixed up and work begun in earnest.

At the end of a season's work, when we have spent, some of us, considerable sums of money on apparatus—sacrificed no end of sleep—put in practically all our spare hou r—we are told that working outside the country is forbidden. After our attempts to enter into a friendly spirit of co-operation with amateur radio men of other nations, we see no immediate prospect of the imposition being removed. Amateur radio is now world-wide in its interests. By its means we are able to converse with a man hundreds of miles away, gradually growing to know him until when we do meet him we feel that we are greeting a very old friend. The International Amateur Radio Union, which was formed in Paris last March, the conference of which the writer had the honour of attending, seeks to bind together the amateurs of the different countries. It can be easily foreseen that if the present restrictions are not greatly moderated, "Great Britain and Northern Ireland"—to use the P.O. phrase, will be virtually debarred from becoming an active member.

With the increasing commercial use of the wave-lengths below the usual band 300-25,000 metres, the position of the private experimenter would seem to be fraught with

considerable uncertainty. No one can deny that the permission to use the bands of wave-lengths of 115-130 metres and 150-200 metres is a very liberal concession on the part of the P.O. authorities. At present it seems that everything will go on swimmingly for the next hundred years. One has, however, but to review the recent history of amateur radio in this country to see that the wave-lengths allotted us have been chopped and changed about in a very unsatisfactory manner. At one time we were allowed the free use of all wave-lengths up to 180 metres, because it was generally thought that such high frequencies were of little use for commercial use. Amateur investigation showed that as the frequency was increased, the signal did not fade below waves of 150 metres. What will be the future of the use of wave-lengths below 300 metres, and above all, what will be the future of amateur radio development on these short wave-lengths ? These questions are well worthy of consideration by all who have the future well-being of amateur radio at heart.

Some little time ago Dr. Palmer, of the College of Technology, Manchester, delivered his first address to the Manchester and District Radio Transmitters' Society, as first President of that society. Dr. Palmer chose for his subject, "The Propagation of Electromagnetic Waves over the Earth's Surface." It was well known, the lecturer said, that the speed of a wireless wave depended upon the substance through which it was passing. By a happy stroke of luck, it so happened that the speed of 186,000 miles per second was true for air as well as for a vacuum. It was not true, however, for a substance such as water. Thus, if a wireless wave were passed through water, the speed would be very much less than 186,000 miles per second. From the formula :

$$\lambda = \frac{v}{n}$$

where λ = wavelength, v = velocity, n = frequency

it will be at once seen that if the speed changes, the wave-length of the signal will change as well, the frequency remaining constant. It will be seen that if the wave-length varies according to the nature of the substance through which it is passing, it would be incorrect to use the term "Wave-length" to denote a definite quantity at the receiving end. It would be far more accurate to mention the frequency in cycles, or kilocycles for convenience, than to speak of something that might have any value at any particular moment, as a constant.

The practical operation of sets has gone steadily on during the last three months, though nothing has been done by the writer. He was, however, glad of the opportunity of conversing across the Atlantic with Mr. Marcuse, G2NM, when that transmitter was at C1BQ a couple of months ago. The speech from C1BQ was at times quite clear, and it was not difficult to make out most of what 2NM said. Three stations in this district using powers under ten watts have been heard in the States and Canada during the past winter. They are 5IK, 2IJ and 6NG. 5IK used 220 volts H.T., with about 0·25 ampere in the aerial. Several stations are rebuilding at the present time. The writer would especially like to hear from amateurs in the district with regard to definite transmission experiments which they have performed. Let us have also definite suggestions for schedule tests—and remembering that we hold our permits for experimental work—let us use them to that end, and all will be well.

Experiments by 2TO.

One is constantly hearing of the ever-increasing use of short waves for amateur communication, and the favourite for Trans-atlantics now seems to be 110 and thereabouts. We have read of FL sending across short distances with a wave of about three metres, but has anybody descended below the 100-metre band to explore the region ? Again, our old frield FL is sending test transmissions on 25 metres in an endeavour to get across to the States. So far as amateurs are concerned, no real attempt has been made to go much lower than 100 metres. 2TO, therefore, thought some good might come from forcing a Hartley single coil radiator designed after Ballantyne down. A few details may be useful before describing results. A four-wire flat top 60 ft. long was used, with an extra 25 ft. twin down lead. Earth was obtained by means of a buried plate and the water mains. The helix consisted of 42 turns on a four-inch side square former. After a few preliminary adjustments, a short test message was sent, and the wave-length was found to be 100 metres. Whilst the radiation

was only ·3 of an ampere, a report was received from 1NA in Finland that the transmission was heard at R6 on two valves. A series condenser was then inserted in the aerial lead, having a capacity of ·0005 and immersed in transformer oil. With four turns of inductance and only 20° of series condenser, a radiation of ·35 was obtained, and a test elucidated the fact that the wave-length in use was 77 metres. In confirmation of this, a card is to hand from 1CF, situated at Créfeld, reporting the test received at R7 with two valves. A further test was made, using a single ⅜-in. strip counterpoise instead of earth, the radiation jumping to ·42 amp., but a test on this arrangement seemed to be below the general run of wavemeters and receivers, for 2TO could not be located by the station keeping observation, neither were any reports received. Without doubt, the radiation was less than would have obtained if a better hot wire ammeter were in use. The type actually used is the ex W.D. variety, and has a resistance, when cold, of 4·5 ohms. This, of course, represents a high loss when operating at the wave-lengths mentioned.

It would, therefore, seem that, although so much attention is being devoted to the 100-metre band, quite a huge field of experimentation is available, and is only waiting exploitation by some of our interested enthusiasts. Unless we (the transmitters) stake our claim, we can rest assured the commercial gang will annex it.

The Trend of Invention.

Loud-Speaker Diaphragms.

The idea of making a telephone diaphragm vibrate as a whole instead of confining it at its periphery is not in itself new. The Brown A type receiver, with its reed and conical aluminium diaphragm, will be familiar to most of our readers. The reason for the conical shape is that it gives the diaphragm rigidity, even though it may be made of very thin material, so that it vibrates as a whole instead of only bowing slightly at the middle. Our Fig. 1 this month illustrates a recently-patented development of the same basic idea. Two cones, A and B, made of suitable light material, are united at their bases and supported from a ring F attached at the base of the apparatus. This support is effected by means of light, flexible members, E, between the circumference of the diaphragm and the ring F, the supporting members E being of such material as not to transmit vibrations to or from the diaphragm. The diaphragm is excited at the apex of one of the cones, which is connected by a link G to an aperiodic telephone movement C, supported from the main frame by a bracket D. The movement C may be of the Baldwin type. The device requires no horn, and it is stated that it reproduces sounds over the entire audible range without resonance or interference. (British Patent 216,946, Western Electric Co., Ltd.).

Another similar patent is illustrated in Fig. 2 (British Patent 197,958, Société Française Radio-Electrique). This patent deals specifically with the means of support of the diaphragm rather than with the actual form of the diaphragm itself. The diaphragm A is supported from a frame D by a large number of radial elastic bands B, stretched between points round the periphery of the diaphragm, and corresponding points on the frame. It is stated in the specification that it has already been proposed to support a diaphragm at two or three points, but this causes uneven stressing of the diaphragm. By having a large number of points of support, as in Fig. 2, the diaphragm is evenly stressed while still being capable of moving freely as a whole. A variety of means of attaching the rubber bands to the diaphragm and the frame may be adopted without departing from the scope of the invention.

Interaction between High-Frequency and Low-Frequency Components in Dual Amplification Circuits.

In spite of the present transient vogue for

dual or "reflex" circuits, very few people seem to give any consideration to what actually occurs, or is likely to occur, when high-frequency and low-frequency inputs are simultaneously applied to the same amplifying valve. The prevalent idea appears to be that the valve first magnifies the H.F. energy in the usual way, and then, after rectification, the L.F. currents may be passed back to the input of the same valve and amplified just as if there were no H.F. component to be dealt with. This would be true in the case of a valve with a long, straight characteristic operated by very weak signals. These conditions do not obtain, however, in practice, as the signals dealt with are not particularly weak, and the characteristic of the valve is not straight at the operating point. The result is that the

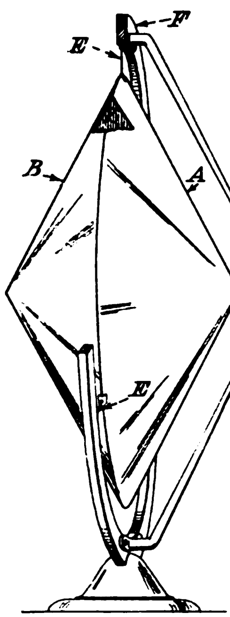


Fig. 1.

H.F. component is modulated by the "reflexed" L.F. component in a manner similar to the action of a grid-control transmitter. this tends to produce a certain amount of low-frequency reaction with attendant inefficiency and tendency to distortion and howling. In a recent patent, however, this effect has been taken into consideration and even turned to good account (British Patent 217,409, P.G.A. H. Voigt). The invention is best explained with reference to Fig. 3. An ordinary one-valve dual circuit is shown. In addition to the ordinary grid potentiometer, some extra grid biassing cells B are introduced so as to give the grid G a negative potential sufficiently to make the valve operate well down on the lower bend of its characteristic. This normally reduces the efficiency, but the low frequency potentials derived from the L.F. transformer take the operating point alternately up and down the characteristic curve, thus varying the amplification of the H.F. signal currents accordingly. This variation of the amplified H.F. output causes a variation in the detected currents and in the L.F. potentials produced across the secondary of the L.F. transformer. In fact, the effect is cumulative, and is, in fact, a species of low-frequency reaction taking place through the medium of high-frequency oscillations. The inventor adjusts his grid bias to suit the particular signal strength being received, and obtains sufficient audio-frequency reaction to effect an overall increase in signal strength. The circuit may be particularly adapted to be unresponsive to weak signals, but to respond to signals greater than a certain strength. The specifi-

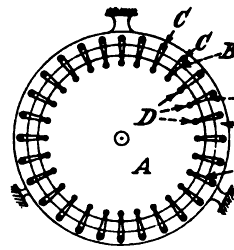


Fig. 2.

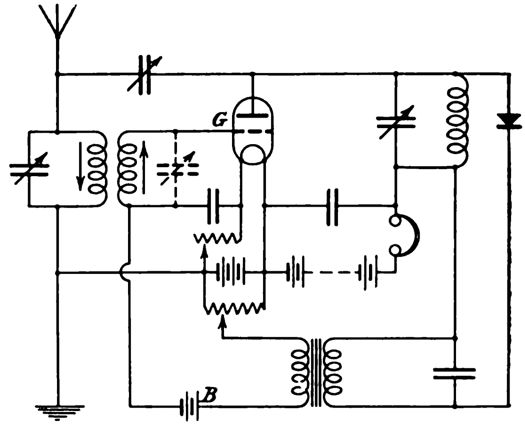


Fig. 3.

cation describes other modifications of this circuit which embody the same principles.

"Soft" High-Power Electronic Discharge Tubes.

The standard practice in thermionic devices has hitherto been either to pump them dead hard, so as to eliminate all but purely electronic conduction, or to allow the presence of sufficient gas to give rise to an arc-like discharge (as in the Tungar tubes and S-tubes). A kind of compromise between these two cases has been patented by the British Thomson-Houston Co., Ltd. (British Patent 216,562). The discharge tube has the usual incandescent electron-emitting cathode which may be thoriated to increase the emissivity. Just enough residual gas may be left to allow a certain amount of ionisation by collision. The positive ions thus formed serve to neutralise the space-charge between anode and cathode, thereby greatly reducing the unwanted potential drop in the device; this reduction of space-charge by ionisation is the main feature of the invention. Certain precautions, however, have to be taken to prevent arcing over by undue ionisation. The residual gas may be argon under a pressure of 20 to 100 microns. Fig. 4

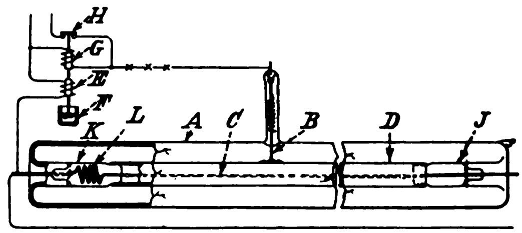


Fig. 4.

shows how the tube may be constructed. The chief point to note is that the cylindrical anode D completely encloses the filament C, and is closed at its ends by insulating re-entrant closures L which may be extensions of the pinches J and K. The electron path is thereby prevented from extending to an undue length at the ends, and producing too much ionisation by collision.

Business Brevities.

Messrs. Burndept, Ltd., realising the possibilities of a great future in the wireless industry in Australasia, have established a branch to be known as Burndept of Australasia, with their head office at 219, Elizabeth Street, Sydney, New South Wales.

* * *

EDISON-BELL PRODUCTS.

Messrs. J. E. Hough, Ltd., have asked us to announce that in our reference to their moulded ebonite products in our June issue we referred to them as being moulded from Ebonite. This, however, is incorrect, as the material used is Eboneum, their own proprietary material.

* * *

IGRANIC ELECTRIC CO., LTD.

A press visit has recently taken place at the Bedford works of Messrs. Igranic Electric Co., Ltd., when the various processes in the manufacture of the well-known Igranic components were a subject of considerable interest to those present. The manufacture, in particular, of Igranic duolateral coils and intervalve transformers is accomplished with the aid of extremely complicated machinery, which is responsible in no small degree for the excellence of the finished articles, although, of course, Igranic components as we know them to-day are the outcome of considerable experiment and research on the part of the technical staff.

* * *

LE CARBONE BATTERIES.

We have received for test an A.D. high-tension battery which has recently been placed on the market by Le Carbone, of Coventry House, South Place, London, E.C.2.. The A.D. cell is somewhat similar to the ordinary Leclanché dry battery, but the chief difference lies in the depolariser, which is not manganese dioxide, but merely air. The cells in the battery submitted are of liberal dimensions, and are capable of withstanding a heavy discharge for a considerable time. It is interesting to note that the terminal voltage was found to be slightly above the rated value, and this did not tend to fall after a long period on load. It was also found that the cell was extremely stable in operation, there being no tendency to crackle or hiss. These features should make it particularly valuable for use on power amplifiers.

POLAR WIRELESS.

Messrs. Radio Communication Co., Ltd., of 34-35, Norfolk Street, London, W.C.2, have just issued an extremely comprehensive catalogue of their receiving apparatus and accessories. Special mention is made of the " Polar Blok " unit system of construction, which should appeal particularly to the experimenter, as it provides almost unlimited scope for the arrangement of circuits . Another particularly interesting feature is a series of special Polar components such as valve fuses, triple condensers, micrometer condensers, universal and cam-vernier coil holders. Altogether, it is one of the most interesting catalogues we have seen for some time, and our readers would do well to acquire a copy, which will be sent post free for the sum of sixpence.

Recent Wireless Publications.

Figures after the title of each publication indicate Volume and Number of Publication containing the article. Where only one number is given, this indicates the serial number of the publication. The abbreviations used in this bibliography will be found in the early issues of "Experimental Wireless."

I.—TRANSMISSION.

KDKA, THE RADIO TELEPHONE BROADCASTING STATION OF THE WESTINGHOUSE ELECTRIC AND MANUFACTURING COMPANY, EAST PITTSBURGH, PENNSYLVANIA.—D. C. Little. (*Proc. I.R.E.*, 12, 3).

THE DESIGN OF TRANSMITTING VALVES—I.—G. L. Morrow (*Exp. W.*, 1, 10).

STOPPING THE KEY-THUMP.—James H. Turnbull (*Q.S.T.*, 7, 10).

II.—RECEPTION.

TELEPHONE DIAPHRAGM RESONANCES.—Prof. E. Mallet, M.Sc. (*W. World*, 253 and 254).

COLLOIDS, THEIR USE IN DETECTORS AND AMPLIFIERS. (*W. World*, 254).

UN NOUVEAU RADIOGONIOMÉTRE AVEC LEVÉE DU DOUTE.—El Bellini. (*L'Onde Elec.*, 29).

L'INFLUENCE DU BROUILLAGE SUR LES RÉCEPTEURS À REACTION.—L. Brillouin and E. Fromy (*L'Onde. Elec.*, 29 and 30).

ÉTUDE EXPÉRIMENTALE DE QUELQUES PROCÉDÉS DE DÉTECTION DES OSCILLATIONS DE HAUTE FRÉQUENCE.—M. Raymond Dubois (*L'Onde Elec.*, 30).

ALIMENTATION DES RÉCEPTEURS RADIOPHONIQUES PAR LE COURANT ALTERNATIF DU SECTEUR.—M. Podliasky (*L'Onde Elec.*, 30).

LA RÉCEPTION DES ONDES DE 50 À 200 MÉTRES (*R. Elec.*, 5, 62).

ON OPTIMUM HETERODYNE RECEPTION.—E. V. Appleton and Mary Taylor (*Proc. I.R.E.*, 12, 3).

THE SCREENING OF RADIO RECEIVING APPARATUS.—R. H. Barfield, M.Sc. (*Exp. W.*, 1, 10).

BUILDING SUPERHETERODYNES THAT WORK.—Part II (*Q.S.T.*, 7, 12).

III.—MEASUREMENT AND CALIBRATION.

RECEIVING MEASUREMENTS AND ATMOSPHERIC DISTURBANCES AT THE BUREAU OF STANDARDS, WASHINGTON, DECEMBER AND NOVEMBER, 1923.—L. W. Austin (*Proc. I.R.E.*, 12, 3).

ON THE MEASUREMENT OF VERY SMALL CAPACITY CHANGES.—Ross Gunn, B.S.E.E., M.S. (*Phil. Mag.*, 283).

A UNIVERSAL METER.—H. E. Dyson (*Exp. W.*, 1, 10)

A HANDY CALIBRATED OSCILLATOR.—N. J. Buckeye (*Q.S.T.*, 7, 10).

IV.—THEORY AND CALCULATION.

SUR LA THÉORIE DU RÉCEPTEUR TÉLÉPHONIQUE.—J. Berthnod (*R. Elec.*, 5, 61).

REGENERATION IN COUPLED CIRCUITS.—E. Leon Chaffee (*Proc. I.R.E.*, 12, 3).

V.—GENERAL.

CONDENSERS: RADIO FREQUENCY AND THE DESIGN OF AN EFFICIENT CONDENSER.—(*W. Age*, 11, 10).

ÉTUDE DE L'EVANOUISSEMENT SUR LES ONDES COURTES.—M. Lardry (*L'Onde Elec.*, 29).

LE PROBLÈME DU VERROUILLAGE EN TÉLÉMÉCANIQUE.—M. Guéritot. (*L'Onde Elec.*, 29).

CORRECTION DE LA DISTORSION DUE À LA CAPACITÉ DES CABLES TÉLÉPHONIQUES, DES AMPLIFICATEURS, ETC.—I. Podliasky (*R. Elec.*, 5, 61).

NOUVEAUX ÉTALONS DE LONGUEUR D'ONDE: LES RÉSONATEURS PIÉZOÉLECTRIQUES.—Michel Adam (*R. Elec.*, 5, 62).

ON PROPOGATION PHENOMENA AND DISTURBANCES OF RECEPTION IN RADIO TELEGRAPHY.—F. Kiebitz (*Proc. I.R.E.*, 12, 3).

THE CAPE COD MARINE SYSTEM OF THE RADIO CORPORATION OF AMERICA.—F. H. Kroger (*Proc. I.R.E.*, 12, 3).

SIGNAL-TO-STATIC RATIO IN RADIO TELEPHONY.—Marius Latour (*Proc. I.R.E.*, 12, 3).

DIGESTS OF UNITED STATES PATENTS RELATING TO RADIO TELEGRAPHY AND TELEPHONY, ISSUED MARCH 4, 1924—APRIL 29, 1924.—John B. Brady (*Proc. I.R.E.*, 12, 3).

A NEW PHOTO-ELECTRIC AND IONIZATION EFFECT.—U. A. Oschwald, B.A., and A. G. Tarrant, B.Sc., F.Inst.P. (*Proc. Phys. Soc.*, 36, 3).

NOTES ON SOME ELECTRICAL PROPERTIES OF THE NEON LAMP.—U. A. Oschwald, B.A., and A. G. Tarrant, B.Sc., F.Inst.P. (*Proc. Phys. Soc.*, 36, 3).

ON CERTAIN PROPERTIES OF THE " OSGLIM " NEON-FILLED LAMP.—J. H. Shaxby and J. C. Evans (*Proc. Phys. Soc.*, 36, 3).

THE PREVENTION OF INTERFERENCE BETWEEN "WIRED WIRELESS" CIRCUITS AND WIRELESS STATIONS.—By E. M. D. (*Exp. W.*, 1, 10).
THE PROBLEM OF HIGH-TENSION SUPPLY—II.—R. Mines, B.Sc. (*Exp. W.*, 1, 10).
THE DESIGN AND CONSTRUCTION OF A 50-CYCLE TRANSFORMER FOR PRODUCTION OF HIGH-TENSION VOLTAGES.—L. E. Owen (*Exp. W.*, 1, 10).
A FEW OBSERVATIONS ON THE RECENT AMERICAN RE-RADIATION TESTS.—Ernest W. Braendle (*Exp. W.*, 1, 10).
THE HEAVISIDE LAYER AND HOW IT MAY BE PRODUCED.—O. F. Brown, M.A. (*Exp. W.*, 1, 10).
ON THE INFLUENCE OF INPUT CONNECTIONS UPON THE OPERATION OF TRIODES.—William D. Owen (*Exp. W.*, 1, 10).
VARIABLE CONDENSER CONSTRUCTION.—George Gentry (*Exp. W.*, 1, 10).
CONSTRUCTIONAL NOTES ON LOUD-SPEAKING TELEPHONES.—E. Simeon (*Exp. W.*, 1, 10).
OSCILLATING CRYSTALS.—H. S. Shaw (*Q.S.T.*, 7, 10).

Correspondence.

Letters of interest to experimenters are always welcome. In publishing such communications the Editors do not necessarily endorse any technical or general statements which they may contain.

To the Editor of EXPERIMENTAL WIRELESS.

DEAR SIR,—May I be allowed to point out a rather bad point in the otherwise good design of a variable condenser by George Gentry in your July issue?

The spindle is shown as a 2 B.A. rod, and thus the bearings consist of threaded rod in bushes, a detail that does not make for accuracy. The constancy of capacity is to a great extent governed by the fit of the bearings and, by attending to this point, a condenser of laboratory standard could be made from the instructions in the article.—Yours faithfully,

J. L. JEFFREE, F.R.A.
(5FR).

[We showed our correspondent's letter to Mr. Gentry, who replies as follows :—

In reply to Mr. Jeffree's criticism of the fact that the journals of the vane spindle are threads running in plain holes. The fit of these, or rather maintenance of fit, depends to a great extent upon the care taken in producing the threads. If good quality screw dies be used, and accurately applied (that is to say, started truly upon a tapered down point, with care used to see that the original truth of the thread is maintained), there should be little trouble on the score of lack of truth in the spindle. There is no doubt that if the threads were screw-cut on a lathe the bearings could be made to work as smoothly as if plain.

The whole idea of the design is to avoid as far as possible complicated mechanical procedures involving the use of machine tools. The right method, of course, would be to turn a spindle from a $\frac{1}{4}''$ bar, and making the portion corresponding to the space between the bearings—less $\frac{3}{16}''$ at top and bottom—$\frac{1}{4}''$ diameter and threaded each end for the locknuts No. 0 B.A. The remainder top and bottom would then be shouldered down to No. 2 B.A. size and only threaded down and up the required distance for the bottom locknuts and the knob and its locknuts at the top, leaving plain $\frac{3}{16}''$ journals. This would entail drilling the vanes and their spacing washers $\frac{1}{4}''$, and fitting No. 0 B.A. locknuts above and below the vanes. The latter nuts could pass up to their threads over the plain journals because their core size is rather over $\frac{3}{16}''$.

A modification that might appeal to those who can use a soldering outfit would be to sheath the portion of the screwed journals (not the full length) top and bottom, after all vanes, washers, and locknuts between bearings were put on by sweating on a short length of thin brass tube $\frac{3}{16}''$ in the bore and about $\frac{1}{4}''$ or a little larger outside diameter. To fit these—now plain journals—the bushes would have to be opened out preferably by the use of a taper broach first and finishing to size with a $\frac{1}{4}''$ reamer.

Nevertheless, the designer does not anticipate that any marked variation in the matter of capacity would occur in this condenser from this cause if the journals were made truly in the first place and fitted without side shake].

To the Editor of EXPERIMENTAL WIRELESS.

DEAR SIR,—With reference to Mr. Clarke's letter in your June issue, might it not be advisable to point out to your readers the advisability of fitting spark gaps between their aerial and earth terminals. I believe that I am correct in saying that whereas at one time the Post Office always earthed their overhead lines during a thunderstorm, they now rely upon lightning arresters and spark gaps only.

On one occasion my aerial was disconnected and sparks were passing very rapidly, and upon disconnecting the gap sparks up to half an inch in length were obtained. A friend, however, who was not so fortunate one day found his curtains alight owing to a similar discharge.

At the time mentioned, and, indeed, almost invariably, these discharges have been observed during a fall of rain or sleet.

It seems to be a general impression that the inclusion of a spark gap leads to inefficiency. This may be so if one of the carbon block type is used, and I have known such a one to effectively prevent short-wave working owing to its capacity, but if two fine steel points are utilised the efficiency does

not appear to be impaired at all. All spark gaps should be enclosed.

Another popular fallacy—at least, so I find it—is that all is well if the aerial is earthed during a thunderstorm, or when it is not in use. This is not so, as pointed out by Mr. Clark, but even when the set is connected, and especially if a series condenser is being used, spark discharges can be obtained. In this latter case it is often useful to connect the largest size honeycomb coil in shunt with the main tuning coil and condenser to discharge the aerial.—Yours faithfully,

M. BLIGH.

174, Wightman Road,
Hornsey, N.8.

DEAR SIR,—The correspondence *re* sparks from the aerial has interested me greatly, as it recalled an experience which occurred to me in the summer of 1922. At the time I was using a straight circuit with a series condenser in the aerial lead. The set worked quite well except for a continuous clicking, which was sometimes heard, but for a long time could not be traced. At last it was found to be due to small sparks jumping across the series condenser which were the source of the trouble. The aerial became charged up to a certain potential, and then sparked through the set. Since then, sparks from 1-32 in. to ⅛ in. have been obtained from rain and sleet. No sparks have ever been obtained from snow.

During the thunderstorm of Monday, May 19, the matter having been recalled by the letter signed "KiloWatt," I lifted the aerial earthing switch and got a fine shower of small sparks from the rain —sufficient to give a weak shock, in fact. The switch was then inadvertently left wide open, and suddenly, as a flash of lightning was seen outside, a fat noisy spark about 1½ ins. long jumped the switch in the room (and I had just been getting shocks from the thing !) Three times this large spark was obtained, each time being due to discharges from cloud to earth. As found later, discharges between clouds themselves do not induce sufficient potentials in the aerial-earth circuit and this seems to have been the experience of Mr. H. A. Clark.—Yours truly,

L. B. COOK.

P.S.—The aerial used in all cases was 55 ft. long, double wire, 9 ft. apart, and about 25 ft. high, rather badly screened.

4, Milton Road.
Bedford.

IN A COAL MINE.

An interesting experiment carried out by the Bristol and District Radio Society. The members are seen in a coal-mine at Midsomer Norton, where they received Morse very strongly, but found speech highly distorted.

Book Review.

THE ELECTROLYTIC RECTIFIER. By N. A. de Bruyne. (Sir Isaac Pitman & Sons, Ltd.). 3s. 6d. net.

This work is a collection of the rather scattered information on electrolytic rectifiers and gives the reader an idea of the work which has been done and the data which has been obtained concerning their action. A brief historical survey is given and numerous references are made to the work of Gunther-Schulze and others on electrolytic valve action. The electrolytic rectifying properties of elements other than aluminium are dealt with, and the effects of temperature and concentration on rectification are discussed with the aid of curves and tables of data. A chapter is devoted to the theory of the action by which anodic rectification takes place, the gas-layer theory being preferred to the older oxide-layer theory. Reasons are given for considering the latter theory untenable and why it is more likely that a thin layer of gas is responsible for non-conduction in the reverse direction. Mention is made of the condenser effect of a rectifier. The last three chapters are of a practical nature, giving details of the construction of charging rectifiers, and the use of electrolytic lightning arresters on power lines is described.

We do not find much to criticise in this book as it is to a large extent a summary of established facts, and a summary does not lend itself to criticism. It is perhaps somewhat brief and we feel that certain portions of the ground—especially those of interest to wireless experimenters—have not been very fully covered. For instance, nothing is said as to the highest periodicity of alternating current at which an electrolytic rectifier will work with sufficient efficiency for practical purposes. Numerous references are given, however, which add to the value of the book. It is well written and the author has evidently taken some pains in collecting his material. As far as we are aware it is the only book dealing exclusively with electrolytic rectifiers and no one seriously interested in the subject can afford to miss reading it.

E. H. R.

Experimental Notes and News.

The Australian Government have entirely altered their regulations governing broadcasting. Hitherto receiving sets were sealed with the particular wavelength allotted to the company to which the purchaser subscribed. The new scheme adopts the principle of the open set, charging a licence fee ranging from 25s. to 30s., according to the radius of the broadcasting station. Two classes of station are authorised, one giving advertising and the other entertainment, the latter receiving revenue licence fees, less 5s. retained by the Government. This scheme limits the number of broadcasting stations in each state. Under the new conditions popular wireless interest in Australia should receive a great impetus.

* * *

It is pleasing to know that the British scheme of broadcasting is very highly thought of by wireless experts from other countries. America in particular envy our freedom from wireless chaos, since they suffer themselves from far too many broadcasting stations. A number of their large stores have stations broadcasting advertisements.

* * *

An extremely up-to-date portable wireless installation is that run by the Belfast-Liverpool Air Line, from Belfast. The aerial is a twin-wire, and there are two portable steel tube masts, one of 50 feet and the other 70 feet. The apparatus is set up in a Leyland motor lorry, and has a 300-watt valve transmitter. In the centre of the floor of the lorry is a petrol-electric generating unit, which supplies power for a motor generator, H.T., and accumulator charging.

* * *

The second exhibition devoted exclusively to the development of wireless, organised by the National Association of Radio Manufacturers, will be held from September 27 to October 8, at the Albert Hall, Kensington.

* * *

On September 22 in Madison Square Garden and the 69th Regiment Armoury, New York, the first Radio World's Fair will be held. It will be run on a very large scale, and among the interesting exhibits will be a section devoted to "New Inventions," where a hundred devices will be shown, including at least three different instruments for transmitting motion photographs by wireless. It is hoped that the first motion pictures will be broadcasted on the opening night of the Fair. There will also be an amateur builders' competition, in connection with which twenty-five prizes are to be awarded. Full particulars may be obtained from James F. Kerr, Hotel Prince George, New York.

EXPERIMENTAL WIRELESS
& The WIRELESS ENGINEER

VOL. I, NO. 12. SEPT., 1924. 1s. NET.

A Personal Note.

WITH this issue, EXPERIMENTAL WIRELESS enters upon a new phase of its career: it has undergone change of proprietors, change of editor, and amalgamation. As EXPERIMENTAL WIRELESS AND THE WIRELESS ENGINEER it will try to serve the interests of its readers even better than heretofore. Perhaps it will not be out of place to say a few words as to the change of editors. Mr. Paul D. Tyers, who has so ably conducted the journal since its beginning; to whom, in fact, the idea of a serious wireless journal is due, has been badly overworked in carrying his idea to fruition, and has been ordered by his doctor to take a long holiday. We are sure his many friends and, in fact, all our readers will join us in our sympathy and in wishing a speedy return to full health and strength.

On our own behalf, we must beg the indulgence of our readers if by any chance they miss a tone and outlook to which they are accustomed. It is no light task to take over the control of an existing journal without the active help and advice of its prior editor.

For the Future.

As regards the future of E. W. & W. E., our readers may be assured that we shall maintain the high quality of its contents. At the same time, it is proposed to widen its scope somewhat.

Probably few of our readers have been in touch with THE WIRELESS ENGINEER, which has hitherto been available only to those actually engaged in the wireless trade. Its aim was to appeal to the professional wireless engineer, engaged in the scientific design of apparatus; and in future issues of E. W. & W. E. we propose to devote a certain amount of space to articles of this nature: an example is the treatise on L.F. Transformers, by Mr. D. W. Dye, which commences in this issue.

While we are thus extending our ground in the direction of scientific theory, it is proposed also to appeal to another type of reader: the new hand who is, shall we say, just graduating from the B.C.L. stage into a full-blown experimenter. These amateurs have usually a very fair *surface* knowledge of wireless, but often suffer from insufficient acquaintance with fundamental principles, particularly as regards alternating currents; and we propose to offer them the chance to overcome any such ignorance.

Our calibration department will continue its work on the same lines as at present. Later, perhaps, it will be possible to enlarge the service, but just at the moment our staff is fully occupied in dealing with arrears of work in hand.

We have in mind several new features, which will, we believe, add both to the attraction and the usefulness of E. W. & W.E.

A Subject-Index.

Those of our readers who, as is so often the case, wish to make frequent reference to

articles or papers on one department or another of wireless work, must often realise how unsatisfactory it is to try and arrange their extracts in alphabetical order, or to look them up in an alphabetical index.

It may not generally be realised that the Bureau of Standards of America has already got out a fairly complete subject classification of wireless matters, which is, in fact, an extension of the Dewey decimal classification of all knowledge, on which most libraries are arranged to-day. In a future issue we hope to give a sketch of the Dewey system, together with the main lines of the Bureau of Standards extension. It will be found that an index to articles and other sources of information, arranged in the numerical order thus arrived at, is a very great help when seeking for information, for it automatically brings together all references dealing with one subject and, moreover, places references to allied subjects close together, thus arranging the whole in a logical scheme. Thus, for example, useful references for transmitter design might in an alphabetical index be found under all sorts of headings: Valves, Hartley, Meissner, High Tension, Reaction, are only a few of the many.

According to the Dewey scheme, all references on the theory of valve transmitters are together, and so is everything dealing with design and construction.

Accordingly, we are making the preliminary arrangements to enable our readers to deal in this manner with all the information we can put before them. In our next issue, we hope, will appear an article on the subject, and we propose also to give the Dewey reference number not only of every article in the future, but also of abstracts, patents, etc. To the best of our knowledge, the only existing wireless periodical in which this is done is the *Radio Service Bulletin* of America, to which we make our acknowledgments.

5XX.

Although few of our readers are likely to build stations quite like 5XX, the detailed description which we publish this month should be not only of interest, but of use to all transmitters. For although the actual station itself is still an experimental layout, still in its design it is in many ways a model. It is interesting to note the great decrease in smoothing arrangements in the three-phase supply as compared with the single-phase, although the former is of a much lower frequency. Unfortunately, the low-power transmitter will probably be unwilling to use six rectifiers for an amount of power that he can handle with one.

Another notable point is the efficiency of the modulator as an amplifier. There is no sign of the usual series of sub-control stages of gradually increasing power: an input of 10-30 watts, corresponding to, say, 100 watts in the H.T. supply to the previous stage, is used to control directly the four 10 kW valves of the modulator, and does so to such an extent that there is 3000 volts of A.C. across the speech choke.

The free use of "tank circuits," *i.e.*, inductively-coupled closed output circuits is also interesting.

Both the drive oscillator and the magnifier feed into such circuits, the stability of which, as compared with the aerial and magnifier grid circuits into which the valves would otherwise feed, is a very useful help in steadying the set. It will be seen that in both cases the input circuits are tuned, although their tune is kept well away from that of the oscillations to be dealt with. Of course, it may well be the case that on the extremely short wave-lengths on which our amateurs are now doing such wonderful work, the losses in such circuits might be unduly heavy. One point we might mention: the values of the radio-frequency chokes in the anode supply circuits are those given to us by the Chelmsford staff; but we think it just possible that they may be incorrect; both on the appearance of the actual coils and on what we should expect from their function in the circuits we should expect higher values.

Transformers.

It is a curious fact that when someone with a nice machine shop decides to become a wireless manufacturer, in two cases out of three he starts off by making an L.F. Transformer. The article by Mr. Dye, which commences in this issue, shows the rashness of such an attempt. He shows that it is by no means a simple matter to find out how an actual transformer will behave when set to do its duty, and it is obvious that the inverse problem, of designing a transformer to give a required performance, is one that may well occupy the most highly skilled electrical engineer for many weeks.

L.F. Transformers.

A non-mathematical abstract of the important article appearing elsewhere in this issue.

ELSEWHERE in this issue will be found the first part of a most important and masterly article by Mr. D. W. Dye, B.Sc., A.C.G.I.

This article will be read with the greatest interest by the professional wireless engineer, for it is the first published thorough investigation into the design of these transformers. For the benefit of the amateur, who is more interested in getting the best performance out of purchaseable transformers, or in designing his own with a minimum of mathematics, we reproduce below some of Mr. Dye's conclusions, in the simplest of language.

The experiments on which the article is based were directed to finding the true resistance and inductance of the transformer windings, and their self and mutual capacities; also the *apparent* resistance and reactance of the primary when the secondary was loaded. From these values can be found the two factors which control the voltage step-up: first, the ratio of the total (alternating) anode voltage which reaches the transformer primary, and, second, the ratio of primary to output voltage. It is obvious that the product of the two factors gives the total step-up from one valve to the other.

Another most important point is the variation of these factors with frequency. It is obvious that for undistorted telephony reception all frequencies should be amplified alike, while for DX telegraphy it is advisable to sacrifice everything else to a high step-up at about 1000 frequency.

In the article itself, it is shown how, starting from assumed values for the windings, etc., the performance can be predicted, and examples are shown of the accurate agreement between prediction and the measured values. But without mathematics one cannot do more than state some general conclusions, some of which, as will be seen, are already well known as the result of practical experience.

It appears, firstly, that the inductance, self-capacity, etc., of transformers are fairly constant, and do not change with frequency or voltage, except perhaps for particularly high voltage such as may occur in high-power loud-speaker work. The effect of the transformer on the rest of the input circuit is that of a large inductance, a small condenser, and a high resistance, all in parallel. Under certain conditions (see below) the apparent shunt resistance is not so high, which means diminished efficiency. A circuit of this type is, of course, a "rejector," and shows a very high apparent resistance at its resonant frequency. But as regards the all-important matter of "step-up," little or no special effect (curiously enough) is shown at resonance, which in ordinary transformers occurs at from, say, 1000 to 3000 cycles. There is, however, a strong *apparent* resonance effect—increased step-up—at a higher frequency, due to magnetic leakage effects. Steps may be taken to counteract this, as will be shown later.

If the grid of the following valve is ever allowed to become positive—that is, if its grid bias is less than the amplitude of the voltage applied by the transformer, the resulting grid current puts on such a load that the step-up falls away. In such conditions the transformer is wasted; it may give no better amplification than a choke or resistance coupling. On the other hand, the "load" of a valve grid circuit *properly adjusted* will sometimes give a better step-up than would be got with no load at all. This is due in part to its capacity, and in part to the fact that, if this second valve has an inductive load in its plate circuit, its input may have "negative resistance," *i.e.*, there is regeneration, which makes up for some of the iron and copper losses in the transformer.

This fact of regeneration may, however, lead to instability, with the possible result of distortion or even howling. It is common practice to use a shunt resistance, of a megohm or so—a "grid leak" in fact—across the secondary, to avoid these effects. It is shown that the effect of this is to give

a flatter curve of step-up for different frequencies. For high and low frequencies the loss is very small, but any "hump" in the curve, which would mean distortion, is considerably reduced. Such resistance loading is therefore beneficial. Mr. Dye gives a value of $\cdot 2 \times$ (turns ratio)^2 megohms as suitable, and points out that the same result is obtained by winding a few turns of wire, say, one to five turns of 18 or 20 S.W.G., over the coil of the transformer, and shorting it.

It was implied in the last paragraph but one above, that the capacity load of a valve *improved* the step-up. This is an undoubted result of the experiments. It was shown that mutual capacity and self-capacity both produced results of the same kind; that, in fact, all the capacities could be represented by one across the secondary. On adding further loading capacities of various values the performance was distinctly improved. Generally speaking, at frequencies below resonance (say up to 1500 cycles) both the factors referred earlier to in this article—primary voltage ratio and step-up—are increased. At higher frequencies, up to the "false resonance" mentioned already, the primary voltage ratio falls, but the step-up of the transformer itself rises: the net effect may be either a rise or a fall. For higher frequencies still, over say 6000 cycles, the loading capacity diminishes the performance.

But it is shown that this may sometimes be improved in another manner, by increasing the magnetic leakage. In a complete transformer this is not practicable directly. But an equivalent change may be made by putting on an inductive load. To reduce the "*k*" of an ordinary transformer by 1 per cent.—the order of change required—would need a load coil of 1 Henry.

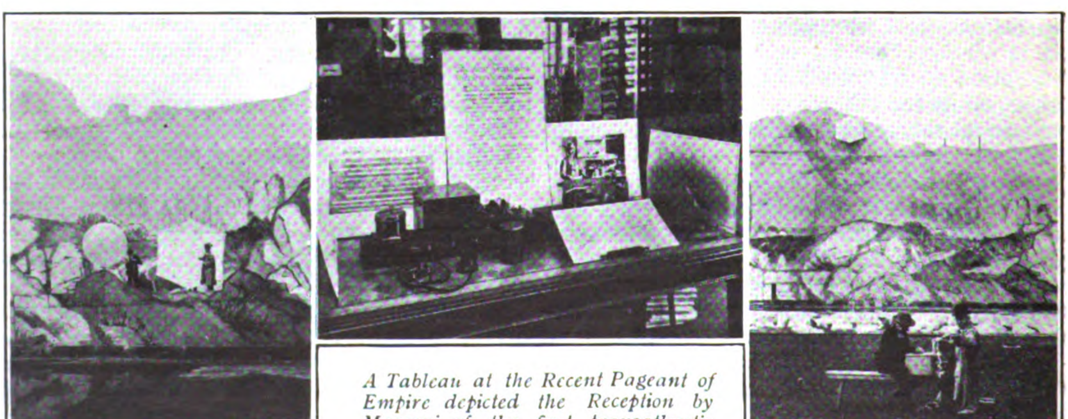
It seems quite certain that by proper adjustment of this kind, a loading capacity will always give improved performance, except in the case of transformers with high ratio or very large primaries. A *total* capacity of about

$$\frac{\cdot 001}{(\text{turns ratio})^2}\ \mu\text{F}$$

seems suitable, but the loading capacity to add can only be found by test: in some cases of not too well designed transformers, the self-capacity is already more than this.

In connection with the loading *inductance* suggested above, to go in series with the capacity, it would be interesting to try the effect of transferring it to the primary, using say 40 000 μH, or, if the "one or two turns of thick wire" is being used, to try the effect of inserting an inductance of 3 or 4 μH (say 5 or 10 turns), *not* round the transformer coils, in series with this.

Lastly, in Mr. Dye's own words, "the most important single property of an inter-valve transformer is the inductance of the primary winding." The lower frequencies will not be properly amplified unless this is sufficient. Mr. Dye recommends a primary of the order of 20 Henries, and points out that few commercial transformers have large enough primaries.



A Tableau at the Recent Pageant of Empire depicted the Reception by Marconi of the first transatlantic message. Left: launching of balloons bearing aerials; right: reception of signal; centre: the original apparatus.

The Use of Low-frequency Amplification for Long-distance Reception.

By S. K. Lewer (6LJ).

IT is not the purpose of this article to describe some means of receiving Honolulu on a crystal set or how to make a special H.F. amplifier, but to show how to increase the efficiency of a receiver of the detector and note magnifier type, which is generally considered to be incapable of covering a distance of more than about 3000 miles except under very favourable conditions.

Of course, the aerial should be high and as free from screening as possible, but much can be done with poor aerials; the writer has obtained very satisfactory transatlantic reception with an aerial whose effective height is about five feet! Care must be taken to reduce the losses due to leakage and capacity to earth to a minimum. Every little helps. As everyone knows, the earth lead should be short and thick in order to reduce the resistance.

If the tuning inductance in the aerial circuit is to be efficient it should be designed very carefully. The wire must be thick, but not too thick—about 20 S.W.G.—because eddy-current losses will probably occur. The turns should be spaced and wound on, say, six ebonite strips in which slots have been cut, so that dielectric losses will be at a minimum.

The condenser in the aerial circuit should preferably be of the low loss type and of about ·0005 μF capacity. Condensers with thin plates generally have high losses, necessitating tighter coupling of the reaction coil. If the whole aerial circuit has a high resistance it will be necessary to "couple up" very closely to obtain oscillations. Now this is a disadvantage which is not generally realised. Any slight adjustment of the reaction coil when it is close to the A.T.I. will vary the wavelength very considerably, and this increases the difficulty in searching for a very faint station, because in order to obtain the greatest sensitivity the set should be only just oscillating and this condition varies with the wavelength. Hence, if the aerial circuit has a low resistance and little reaction is needed, searching is made easier. The set may be made to oscillate more readily by taking the lead from the grid to a point higher up than the aerial tap on the A.T.I.

As regards the valves to be used, it may be said that ordinary "R" valves are quite suitable, but a soft rectifier may give better results. The chief point to observe in adjusting the set is that a quiet circuit is absolutely necessary. It is utterly impossible to read a faint signal through the multitude of "rushing" noises which is inherent in some sets with two or more valves. The noise is reduced by cutting down the filament and anode voltages. The H.T. voltage on the rectifier should be in the vicinity of 25 volts if it is a soft valve, and that on the amplifiers about 20 volts. Three volts on the rectifier filament, and perhaps 2½ volts on the amplifiers should suffice. In most cases not more than one note-magnifier will be needed. This method of reducing the filament-to-anode current also limits the jamming caused by "mush," etc.

Naturally the efficiency of the set will vary if the voltages are varied, and tests should be made to counteract this by finding the best grid potential. The simplest way to do this is to use a potentiometer, but much can be done by trying the effect of taking the lead from the grid to various points on the filament circuit. These tests must be made on faint signals, as in all probability loud signals, such as those emanating from the local B.B.C. station, will be horribly distorted due to the overloading of the valves. Another point of which care must be taken is "overlap." To detect if overlap is present proceed in this way:

gradually tighten the reaction coupling: if the set bursts into oscillation with a click and remains in this condition when the reaction coil is withdrawn beyond the point at which oscillation began, then overlap is present. Obviously this must be eliminated in order to obtain maximum sensitivity. This is most easily done by connecting the direct grid lead to a different point on the filament circuit. At the same time the efficiency will be improved. Varying the H.T. voltage or the size of the reaction coil often assists in smoothing out the oscillation point. A variable grid leak is sometimes useful, but some of those on the market are variable only once when they are first screwed up, after which they remain fixed.

It is a good plan to control the normal grid potentials by means of a potentiometer, but this is not absolutely necessary in order to obtain the highest efficiency if care is taken to connect each grid lead to the best position on the filament circuit. The sensitivity of the valve is due to the presence of the grid, and hence the utmost care must be used in its control.

The grid condenser and leak should have the usual values, but it is advisable to try soft rectifiers without them.

The intervalve transformer must be of the high-ratio type, and preferably of well-known make. Cheap transformers are often inefficient because they are not wound with sufficient wire. The usual shunting condenser of about ·001 mfds. should be used. The telephones should be of high resistance, as there is bound to be some loss in the transformer if low resistance telephones are used.

At the writer's station, unfortunately, an efficient aerial cannot be erected, and the one in use at present is 10 to 20 feet below the neighbouring housetops. Within 15 feet of the aerial there are about 500 square feet of metal in the form of roofs. A soft Dutch valve is used for rectifying and an "R" valve for amplifying. The transformer is an ex-W.D. one, and the telephones are Brown's "A" type of 8000 ohms resistance.

Regarding the results obtained with this set, it may be mentioned that the writer has on several occasions listened for American amateurs, and has logged 308 of them at a rate of about 12 per hour on the average. Six American Broadcasters have been heard, WGY and KDKA being easily audible 15 feet from the home-made loud-speaker on a good night. Three amateur stations on the Pacific Coast of U.S.A. have been read on one valve only, but the writer admits that these were "freaks." However, such stations as 1XW, 1BQ, 3OT, 4BZ, 9BL can be heard several feet from the loud speaker almost any morning. All of the above stations can be read on one valve with an indoor aerial.

In conclusion, perhaps it would be of interest to compare the relative advantages and disadvantages of H.F. and L.F. amplification for DX work.

Comparison of the relative advantages and disadvantages of H.F. and L.F.

Advantages.	*Disadvantages.*
H.F.	
1. Selectivity.	1. Extra difficulty in tuning.
2. Sensitivity.	2. No reduction of aerial circuit resistance.
	3. Extra capacity in detector grid circuit.
	4. Body-capacity effects.
L.F.	
1. Very easy tuning.	—
2. Reduction of aerial circuit resistance.	

The first advantage of H.F. in the table tends to become a disadvantage in practice, because it is so very difficult to find a really faint station if the receiver is selective. It is true that an H.F. valve increases the sensitivity, but some of this is lost by the extra capacity which is involved in the detector grid circuit. If an H.F. amplifier is used reaction is generally coupled to the tuned-anode coil or the transformer, as the case may be. This means that the resistance of the aerial circuit is not reduced; but when reaction is coupled to the A.T.I. the effective resistance may be decreased to and below zero if necessary, so that the strength of signals is increased. If "double-reaction" is used, that is, if the three coils are coupled together, adjustments become very critical, and quick tuning is by no means easy.

This article does not take into comparison the multi-valve super-heterodyne set, which is undoubtedly the most reliable of all sets for distant reception.

The Performance and Properties of Telephonic Frequency Intervalve Transformers.

By D. W. Dye, B.Sc., A.C.G.I.

This important article, by the head of the Electrical Measurements Department at the N.P.L., will be studied with great interest by all technical readers. An abstract, in non-mathematical language, will be found elsewhere in this issue.

Summary.

Methods are described for measuring the effective primary inductance and resistance of telephonic frequency transformers.

It is shown that when reactance and resistance are plotted in a convenient manner the result is a circle diagram.

The analysis of the effective components of inductance, capacity and resistance corresponding to the circle diagram is then shown and is developed to include the effects on primary effective reactance and resistance of mutual and secondary capacity, shunt resistance on the secondary and the attachments of a valve grid-filament circuit.

The means of evaluating secondary inductance and self-capacity are shown. The effects of the foregoing quantities on the ratio of the transformer are then examined experimentally and theoretically and the close relationship of ratio to the coefficient of coupling shown.

The results of the complete analysis are applied to the determination of the amplification factor of the transformer and a number of conclusions are drawn therefrom.

1.—Introduction.

Intervalve transformers are a very commonly used means of coupling the stages of amplifiers used for various purposes in which it is required to magnify weak currents of telephonic frequency.

Very little information has been published on the properties of such transformers or on the methods of testing their operation and determining the qualities that are desirable in them in order that they may best suit the circuits to which they are applied. One test which is commonly applied is to measure the effective amplification of voltage given by a valve and transformer. This may be expressed as the ratio of the secondary voltage produced by the transformer, when connected to the grid of another similar valve, to the voltage applied to the grid of the first valve in whose anode circuit the primary of the transformer is connected.* This test is very valuable and is a direct measure of the overall performance of a transformer. As a means of comparing various types of transformer also it is probably indispensable. Such a test, however, has very small power of analysing the various factors entering into the overall performance.

It was thought that more insight into the behaviour of such transformers would be obtained by carrying out direct measurements of the effective inductance, resistance and other inherent properties of the windings. The present investigation is an attempt to analyse the transformer experimentally and theoretically under the conditions of use. The results have proved highly interesting and somewhat remarkable, and although it has not been possible to separate completely all the quantities involved, a sufficiently complete analysis has been obtained in a manner which is capable of giving much guidance in design.

2.—General Considerations.

Statement of the case.

The function of an intervalve transformer is to receive on its primary winding as large a fraction as possible of the alternating voltage set free in the anode circuit in which it is connected. It should then develop at its secondary terminals—connected to the grid circuit of the ensuing valve—as high a voltage as possible. Further, the ratio of the input voltage to the first valve to that given by the transformer to the ensuing valve should be invariable with regard to frequency and amplitude. It is, of course, realised in making the above statement that the most perfect transformer from this point of view may fail by its very perfection on account of the instability which may be produced and which will result in the self-generation by the system of oscillations of audible frequency constituting one form of the troublesome malady known as " howling."

* F. E. Smith and H. C. Napier—On the Measurement of Amplification given by Triode Amplifiers, at Audible and at Radio Frequencies.—*Proc. Phys. Soc.* 1920, Vol. 32, p. 116.

In the present investigation, however, no account is taken of this possibility in any part of the discussion or conclusions.

Referring now to Fig. 1, representing a

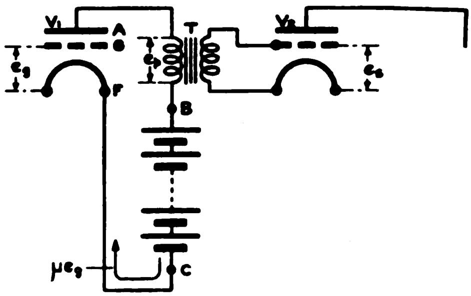


FIG. 1.

typical use of an intervalve transformer T, we have, applied to the grid of valve V_1, an alternating voltage, e_g, the source of which, for the moment, does not concern us. As a result of this voltage, a voltage e_g is produced in the anode circuit ABCF; of this voltage a fraction e_p is applied to the primary of the transformer, resulting in a secondary voltage e_s which is applied to the grid-filament circuit of the valve V_2. The duty of the transformer is to give a ratio e_s/e_p as large as possible and to keep this ratio independent of amplitude and frequency. Now the essential electrical quantities involved can be represented as in Fig. 2, in which the valve V_1 and its batteries have been replaced by a resistance R_a assumed constant and pure and a source of alternating voltage of value μe_g. The valve V_2 is assumed to be replaced by an impedance Z_g consisting of a capacity C_g and a series resistance r_g. A variety of quantities enter into the electrical representation of the transformer, but for the moment, as regards the current i_p entering at the terminals, the primary winding can be represented by a simple impedance Z_p and the secondary winding can be represented in a like manner.

The ratio $\frac{e_s}{\mu e_g}$ may now be considered as the product of the two quantities q and σ, where q is the primary voltage factor and σ the ratio of e_p to e_s. We have

$$q^2 = \left(\frac{e_p}{\mu e_g}\right)^2 = \frac{Z_p^2}{X_p^2 + (R_p + R_a)^2},$$

in which X_p and R_p are the reactance and resistance components of Z_p, while σ depends mainly upon the ratio of the numbers of turns of primary and secondary windings. If therefore we measure X_p and R_p under various conditions and over a considerable range of frequencies, we can determine the performance of the transformer under these conditions. It is to be anticipated also that a separation of the internal constants of the transformer can to a considerable extent be made by observation of the change in effective primary impedance and in ratio when various external conditions are varied. Since an intervalve transformer contains thousands of turns in its windings, in a confined space, it is to be further expected that the distributed capacities of the windings will play an important part in its behaviour.

The transformer may therefore be considered as a mutual inductance possessing all the parts indicated in Fig. 3, in which R_t and L_t represent a tertiary closed circuit imitating the hysteresis and eddy current effects due to the iron core and C_m represents distributed capacity between primary and secondary windings. The meanings of the other quantities are obvious.

The complete solution of this case can be expressed as a determinant, but the reduction of any part of it to a working equation becomes too complicated to enable the bearing of the various factors to be visualised;

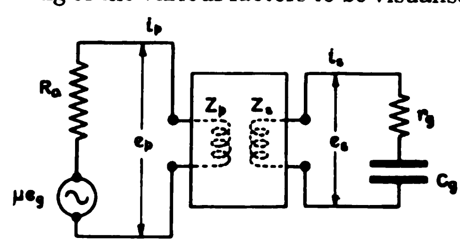


FIG. 2.

in addition L_t and R_t are variable with frequency and current, and the effective mutual capacity C_m will depend upon the potential differences between any chosen points on primary and secondary circuits as determined by the complete electrical system including the external circuit. As regards this latter point, in practice the transformer is commonly connected as shown in Fig. 4. The impedance of the anode battery between the points A, B is small compared with the rest of the circuit, even without the con-

denser C. When this is used, as is common, and has a value of the order 1 or 2 μF, it virtually amounts to connecting the terminals P O, S I together so far as the alternating voltages are concerned. This results in a simplification of the equivalent circuits of the transformer to those shown in Fig. 5, in which also the iron losses have been transferred as a load Z_s (not necessarily invariable with frequency) on the secondary winding. The equivalent grid capacity and resistance have been merged into the secondary capacity and impedance. This diagram represents the simplest form and possesses the smallest number of variables to which an intervalve transformer can be reduced. Before giving the evaluation of the equations connecting the various voltages and currents, it is convenient to describe the methods and some results of the experiments on the measurements of effective inductance and resistance of the primary winding and of the effective ratio of transformation.

3.—Measurement of effective primary impedance and of voltage ratio of transformer.

The measurement of an inductance of many Henries having a resistance of many thousands of ohms is not very easy, especially when these measurements are required at small voltages. Variable mutual or self-inductances of range expressed in Henries are not easily available, and, further, if one arm of a bridge is allowed to be of several hundred thousand ohms in impedance, the effects of stray capacities become very troublesome, and the measurements are uncertain unless great precautions are used.

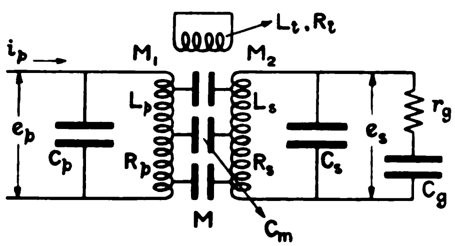


FIG. 3.

In the light of previous experiments, the method finally adopted consisted of a mutual inductance bridge with four equal arms of 1000 ohms each. The arrangement is shown in Fig. 6. The measurements consist in observing the change in effective inductance

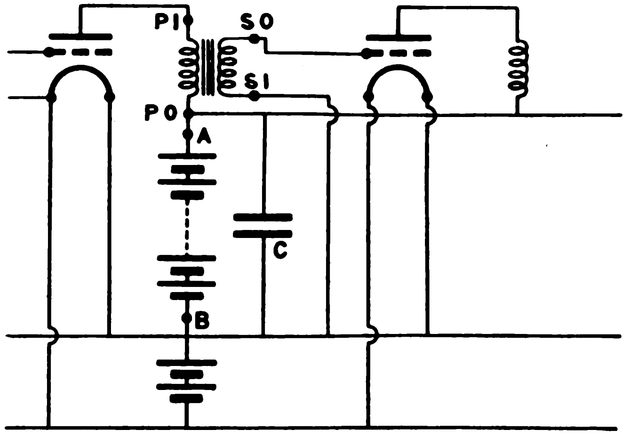


FIG. 4.

and resistance of the non-inductive resistance coil S when shunted by the primary of the transformer. A definite voltage is conveniently applied to the ends of S by the help of the thermoammeter A, and a shunt resistance T across the bridge. The whole bridge resistance between *a* and *b* is almost invariable under all experimental conditions, and is nearly 1000 ohms. The mutual inductometer is of 10mH range: the variable resistance *r* requires to be known to 0·01 ohm, and may reach values somewhat greater than 10 ohms. The point *b* of the bridge is directly earthed, and greatly stabilises it; doubtless a Wagner earth would be superior from the point of view of rendering capacities of the transformer to earth of no consequence, but these effects are of no particular importance in the present investigation, since less than 1 per cent. uncertainty is produced by them.

An Ayrton-Mather low-reading electrostatic voltmeter serves to read or to see the secondary voltage of the transformer. This voltmeter must be disconnected when the observations are made, because of the large effects produced on the effective primary inductance and resistance by the capacity of the voltmeter. As will be seen later, the voltmeter capacity has a negligible effect on secondary voltage. The low-reading volt-

meter is rather a luxury in such experiments, but if desired a valve instrument of the Moullin type could doubtless be used instead.

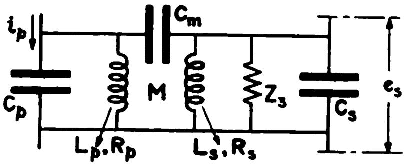


FIG. 5.

The procedure consists in observing the values of M and r, first with the transformer disconnected from S, and then after shunting it across S. Before making the second observation, the voltmeter is connected to the secondary of the transformer and the bridge current adjusted so as to give the desired primary or secondary voltage. The effective resistance and inductance of a shunt circuit in terms of the change in effective resistance and inductance of the resistance S is given as follows : if the pure resistance S is shunted by R and L in series, and then has an apparent resistance and inductance S_0 and L_0, then

$$R = \frac{SS_0(S-S_0)-SL_0^2\,\omega^2}{(S-S_0)^2+L_0^2\,\omega^2}$$

$$= \frac{S^2\Delta S}{\Delta S^2+L_0^2\,\omega^2} - S$$

in which $\Delta S = S - S_0$ and

$$L = \frac{S^2 L_0}{\Delta S^2+L_0^2\,\omega^2}$$

In the equal arm bridge here used L_0 is equal to $2\,(M-M_0)$ where M_0 and M are the readings on the inductometer before and after connecting the transformer primary across S, and ΔS is equal to the difference between the values of r before and after connecting the transformer.

We have therefore

$$R = \frac{S^2\Delta R}{\Delta R^2+(2\Delta M)^2\,\omega^2} - S \quad .. \quad (1)$$

and

$$L = \frac{S^2 2\Delta M}{\Delta R^2+(2\Delta M)^2\,\omega^2} \quad .. \quad (2)$$

By choosing S equal to 1 000 ohms we get a very convenient multiplier of 10^6, thus enabling the readings to be taken on the 10mH inductometer. In a poor transformer, however, M may become larger than 10mH. In this case S may be conveniently chosen as 500 ohms.

When the current through the bridge is reduced to such a value that the secondary voltage across the transformer is less than 2,

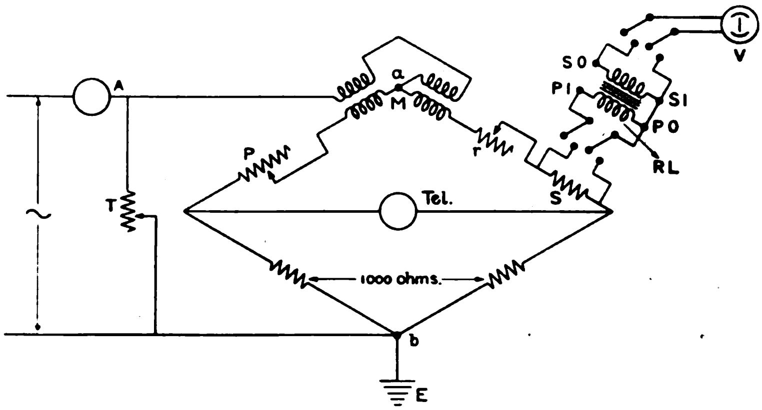


FIG. 6.

favourable external conditions are required in order to obtain good sensitivity, since there is not then more than about 1 volt on the whole bridge. As will be seen later, a typical transformer may have an effective primary reactance of no less than 500 000 ohms in certain regions of frequency, so that the change in r representing change in S is only about 2 ohms. For an accuracy of 1 per cent. therefore r must be observed to 0·02 ohm, and this is an arm of 1 000 ohms resistance. Since, however, practically the whole of the bridge consists of 4 manganin coils of 1 000 ohms each, the balance is remarkably stable.

When observing the effects of added capacity across the secondary or as added mutual capacity, a standard low range variable

air condenser was used. The effects of resistance across the secondary were also studied, and for this purpose grid leaks previously calibrated at telephonic frequencies were used.

A typical series of observations is given in Table 1 below, together with the reduced values of R_p, L_p and X_p, the effective resistance, inductance and reactance of the primary winding.

TABLE 1.

EFFECTIVE PRIMARY RESISTANCE, INDUCTANCE AND REACTANCE OF INTERVALVE TRANSFORMER WITH P O AND S I COMMON AND NO CONNECTIONS ACROSS THE SECONDARY.

Frequency. cycles per sec.	Observed r Difference.	Observed M Difference.	R_p	L_p.	X_p.
	Ohms.	μH.	Ohms.	Henries.	Ohms.
500	4·49	5 010	3 450	9·93	31 200
800	2·73	1 794	7 200	10·82	54 300
1 000	2·22	1 014	12 500	12·23	77 000
1 200	1·93	565	24 300	14·82	111 800
1 400	1·88	319	54 500	18·54	163 000
1 500	1·85	+225	85 000	21·07	198 500
1 600	1·81	+156	135 300	23·84	239 600
1 700	1·78	+102	224 000	25·85	276 000
1 750	1·76	+64	345 500	25·10	276 000
1 800	1·74	+42	442 000	21·36	+241 600
1 850	1·74	+13	557 000	8·36	97 000
1 900	1·71	—10	569 000	—6·54	—78 000
1 950	1·71	—30	493 000	—17·31	—212 000
2 000	1·71	—46	400 000	—21·56	—271 000
2 100	1·74	—85	216 000	—21·14	—279 000
2 200	1·75	—116	130 000	—17·43	—241 000
2 500	1·76	—187	51 000	—10·37	—163 000
3 000	1·75	—256	17 000	—5·33	—100 500

The curves corresponding to R_p and L_p are shown in Fig. 7. The changes in them are very great as the frequency passes through the resonant region. In this region, therefore, frequencies near one another must be used if accurate delineation is required; the frequencies must also be known with considerable precision.

It will immediately be seen that these curves are those corresponding to a system having a well-defined resonant frequency. Now one of the properties of such a system is that if we plot effective resistance against the corresponding effective reactance the points should lie approximately on a circle. In Fig. 8 are shown the corresponding values of resistance and reactance plotted—as dots in circles—in this manner. It will be seen that the points lie upon an astonishingly good circle. It is of interest to consider the simplest kind of circuit which can produce a circle when its properties are treated in this manner.

4.—Circle diagram and its relationship to the properties of a circuit.

If we take the simple circuit shown in Fig. 9 (a), we shall find that the equivalent R_0 and X_0 with respect to the external current i_0 have such values as to give a perfect circle when plotted in the manner shown in Fig. 8. Thus—

$$i_0(R_0+L_0a)=e_0=i_1La=i_2S=i_3\frac{1}{Ca}$$

where $a=j\omega$,

and $i_0=i_1+i_2+i_3$

$$\text{whence } R_0=\frac{SL^2\omega^2}{S^2(1-LC\omega^2)+L^2\omega^2} \quad .. \quad (3)$$

$$\text{and } L_0=\frac{S^2L(1-LC\omega^2)}{S^2(1-LC\omega^2)+L^2\omega^2} \quad .. \quad (4)$$

Now if we let $a^2=(\text{Radius of circle})^2=(R_0-\frac{1}{2}S)^2+(L_0\omega)^2$

we get $a^2=$

$$\frac{S^2\left[\{L^2\omega^2-S_2(1-LC\omega^2)^2\}^2+4S^2L^2\omega^2(1-LC\omega^2)^2\right]}{4\{S^2(1-LC\omega^2)^2+L^2\omega^2\}^2}$$

$=S^2/4$.

For all values of ω therefore the points lie on a circle of diameter equal to S, and with its centre on the axis at the point $R_0=\frac{1}{2}S$. Now such a circle, although approximately representing the transformer primary, cannot quite do so, since the inductance L_1 has in practice a resistance R, which is shown by the relatively very small R_0 at the point O

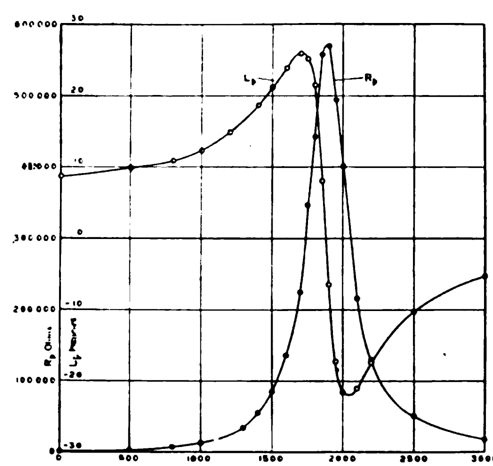


FIG 7.

on Fig. 8, corresponding to a frequency 0. Now this resistance R, although of little consequence at frequencies corresponding to the lower portion of the circle, has a considerable influence on the diameter of it. A further effect is to cause the circle to be displaced horizontally by a small amount, so that its centre lies to the left of the R axis. The experimental results are sufficiently accurate to show this, as will be seen by close inspection of the points. A closer approximation to the experimental and the actual case is given by (*b*) of Fig. 9, where an R term is included, and the shunt resistance S now has a different value from that corresponding to Fig. 9(*a*).

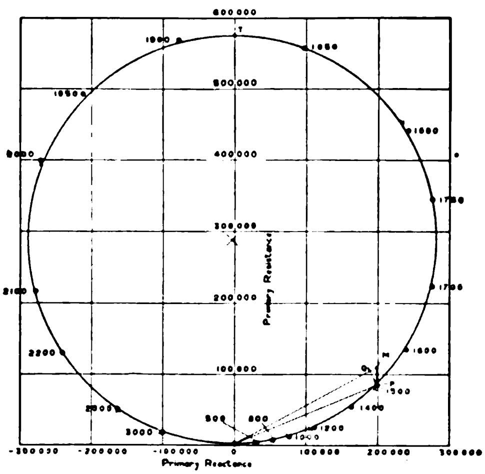


FIG 8

Calculating the effective values of R_o and L_o for case (*b*) the accurate expressions are

$$R_o = \frac{S(R^2+SR+L^2\omega^2)}{(R+S[1-LC\omega^2])^2+(L+RSC)^2\omega^2} \quad .. \quad (5)$$

and

$$L_o = \frac{S^2\{L(1-LC\omega^2)-R^2C\}}{(R+S[1-LC\omega^2])^2+(L+RSC)^2\omega^2} \quad .. \quad (6)$$

When $LCw^2=1$, these become to a very close approximation

$$R_o\max = S - \frac{RS^2C}{L+RSC}$$

$$= \text{Diameter of circle} = \frac{SL}{L+RSC} \quad .. \quad (7)$$

$$L_o = 0$$

It is seen that the introduction of the R term has considerably complicated the expressions for R_o and L_o, so that the diameter of the circle is no longer equal to S, and the exact evaluation of the four constants L, C, S and R from a series of observed values of R_0 and L_0 is not quite so easy. It would, in any case, obviously be unwise to attempt to separate L and C at a region of frequency near that at which $LC\omega^2=1$. We will, therefore, consider the case where $LC\omega^2$ is not nearly unity, *i.e.*, the lower portion of the circle. Terms containing R^2 become negligible, and the expressions reduce to

$$R_o = R_p = \frac{S(L^2\omega^2+RS)}{L^2\omega^2+2RS+S^2(1-LC\omega^2)^2} \quad .. \quad (8)$$

and

$$L_o = L_p = \frac{S^2L(1-LC\omega^2)}{L^2\omega^2+2RS+S^2(1-LC\omega^2)^2} \quad .. \quad (9)$$

or

$$X_p = L_p\omega = \frac{S^2L\omega(1-LC\omega^2)}{L^2\omega^2+2RS+S^2(1-LC\omega^2)^2} \quad (10)$$

in which R_p and L_p represent the effective resistance and inductance of the primary of a transformer.

The separation of the quantities L, C, S and R will now be considered.

Equation (10) may be written

$$\frac{1}{X_p} = \frac{1-LC\omega^2}{L\omega} + \frac{1}{S^2} \times \frac{L\omega}{1-LC\omega^2} + \frac{2R}{SL\omega(1-LC\omega^2)} \quad (11)$$

Let $\dfrac{1-LC\omega^2}{L\omega} = P$

we then have

$$\frac{1}{X_p} = P + \frac{1}{S^2} \times \frac{1}{P} + \frac{2R}{SL\omega(1-LC\omega^2)}$$

We can treat the term $\dfrac{2R}{SL\omega(1-LC\omega^2)}$ as a separate correction to be applied afterwards, as will be seen later.

Taking then, $S^2P = S^2P^2X_p + X_p$

we have

$$P = \frac{1}{2X_p}\left(1 \pm \frac{1}{S}\sqrt{S^2-4X_p^2}\right)$$

If, therefore, we choose points having observed values X_1 and X_2 of X_p at known values of ω equal to ω_1 and ω_2 as given by the circle, we can write down two equations,

$$P_1 = \frac{1}{2X_1}\left(1 \pm \frac{1}{S}\sqrt{S^2 - 4X_1^2}\right) \quad .. \ (12)$$

and

$$P_2 = \frac{1}{2X_2}\left(1 \pm \frac{1}{S}\sqrt{S^2 - 4X}\right) \quad .. \ (13)$$

The significance of the $\pm$ sign in the bracket is that, for points on the circle below the horizontal diameter the sign is +, and for values above this diameter the sign is —. At the two points on the circle where the horizontal diameter cuts it, the expression under the square root becomes zero.

Now $P_1 = \frac{1}{L\omega_1} - C\omega_1$ and $P^2 = \frac{1}{L\omega_2} - C\omega_2$

so that
$$L = \frac{\omega_2^2 - \omega_1^2}{\omega_1\omega_2(P_1\omega_2 - P_2\omega_1)}$$
$$= \frac{n_2^2 - n_1^2}{n_1n_2(P_1\omega_2 - P_2\omega_1)} \quad .. \ (14)$$

and
$$C = \frac{P_1\omega_1 - P_2\omega_2}{\omega_2^2 - \omega_1^2} = \frac{P_1n_1 - P_2n_2}{2\pi(n_2^2 - n_1^2)} \quad .. \ (15)$$

It has been noted above in equation (7) that the diameter of the circle does not equal S, so that we cannot use the experimentally known diameter in equations (12) and (13) in order to determine P_1 and P_2.

But if we choose suitable values of X_1 and X_2, an uncertainty in S can be made of little consequence. The best procedure is first to calculate L and C assuming S to be equal to the diameter of the circle, and then, assuming these values of L and C in the equation

$$S = \frac{LR_p\,(max)}{L - CRR_p\,(max)} \quad .. \quad .. \ (16)$$

—deduced from equation (7)—we can find a more accurate value for S. This new value is then used in equations (12) and (13) in determining P_1 and P_2. One such stage of successive approximation will give results for L and C which are not in error by ½ per cent.

Suitable points to choose for X_1 and X_2 are, one on either side of the R axis, at which they have values of the order of one quarter of the diameter of the circle.

An example taken from Fig. 8 will illustrate the procedure.

Let the points chosen be

$n_1 = 1500(\omega = 9424)$ and $n_2 = 2500(\omega = 15700)$.

The corresponding values of X_1 and X_2 are $X_1 = 198\,500$ ohms and $X_2 = -163\,000$ ohms. Using first the value $S = 576\,000 =$ (dia. of circle), these give for P_1 and P_2 the results

$$P_1 = \frac{1}{397000}\left(1 + \frac{1}{576000}\sqrt{576000^2 - 397000^2}\right)$$

$$\text{and } P_2 = -\frac{1}{326000}\left(1 + \frac{1}{576}\sqrt{576^2 - 326^2}\right)$$

whence $P_1 = 4{\cdot}35 \times 10^{-6}$ and $P_2 = -5{\cdot}60 \times 10^{-6}$ so that $L = 8{\cdot}81$ henries.

Also C, by formula (15), is equal to

$$\frac{4{\cdot}35 \times 10^{-6} \times 9426 + 5{\cdot}60 \times 10^{-6} \times 15700}{15700^2 - 9424^2} = 814\mu\mu F$$

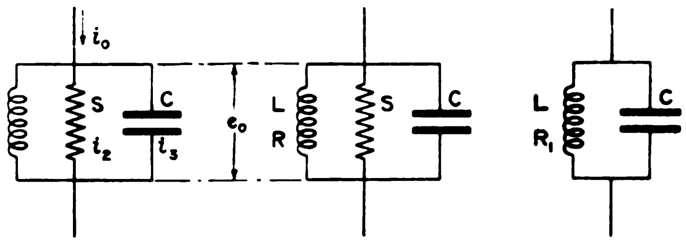
Using these values of L and C in equation (7a), and assuming the d.c. value of 1000 ohms for R, we get for S the corrected value, $S = 608\,000$ ohms. The revised values of P_1 and P_2 become $4{\cdot}43 \times 10^{-6}$ and $-5{\cdot}66 \times 10^{-6}$ respectively, giving for L and C the corrected values

$L = 8{\cdot}68$ H.

and $C = 825$ $\mu\mu$F.

The analysis yields therefore the following effective values for the primary winding :—

$L = 8{\cdot}68$ H; $C = 825$ $\mu\mu$F; $S = 608000$ ohms; and R (assumed equal to the d.c. value) = 1000 ohms.



(a) (b) (c)

FIG. 9.

Returning now to the term $\dfrac{2R}{SL\omega(1-LC\omega^2)}$, which was neglected in equation (11), we should have used terms of the form

$$\frac{1}{X}-\frac{2R}{SL\omega(1-LC\omega^2)} \text{ instead of } \frac{1}{X}$$

in equations (12) and (13) when determining P_1 and P_2. If the values already determined for S and L are inserted in the correction term we shall see that a value of P_1 about 0·8 per cent. smaller and a value of P_2 about 0·4 per cent. greater should have been used in calculating L and C. If these corrections are applied, it will be found that L will only be increased by 0·3 per cent. and C will be increased by a completely negligible amount. We can therefore safely take the simplified form of equation (11) when calculating L and C.

Using the values of L, C and S thus determined, values of R_p and L_p have been calculated by formulæ (5) and (6) for a number of frequencies. These points are marked by crosses on the circle in Fig. 8, and will be seen to give very good agreement with the observed values at these same frequencies. This agreement indicates that L, C and S do not vary much with frequency at the small magnetisation necessary to produce a secondary voltage of 2.

The circle diagram affords a very convenient graphical means of observing the voltages and their phase relations in the primary winding and the associated valve circuit. Thus, at any frequency, such as that given by P on the circle corresponding to $n=1500$, we may draw PM equal to the anode resistance R_a of the valve; if now we join OM we have a triangle in which we may consider OM equal to the total voltage μe_g in the equivalent circuit of Fig. 2. PM is the voltage drop in R_a and OP is the voltage e_p across the primary of the transformer. The phase relationships of these voltages is also shown, and the ratio OP/OM gives the fraction q of the voltage μe_g which is acting on the primary winding of the transformer.

The circle diagram will be found a very clear and simple method of visualising at a glance the behaviour of a mesh circuit possessing any parallel combination of resistance, capacity or inductance towards another circuit in which it is placed. The locus of the end of the impedance vector travels round a circle when any one of the four quantities S, L, C or ω is continuously varied. The circuit need not contain both capacity and inductance, but in such a case only a semi-circle will be obtained; also, for the particular case where $S=\infty$ the circle becomes of infinite diameter and the vector impedances all lie on one line. If we take a common oscillatory circuit with series resistance and infinite shunt resistance, the circle is not quite perfect, since the vector is not zero at zero frequency, but in most cases the diameter is so large compared with the resistance vector that the want of perfection is inappreciable. There would appear to be room for the development of this method of studying the relationship of one circuit to another.*

Returning now to Fig. 9, the quantities L, R, S and C require examining. L as analysed above is clearly the true effective self-inductance of the primary winding. R is a term depending upon the copper losses in primary and secondary, and probably has a value in the neighbourhood of R_1+R_2/σ_0^2, where R_1 and R_2 are the d.c. resistances of primary and secondary windings and σ_0 is the ratio of the turns. C, however, is an equivalent capacity, involving the three capacities of Fig. 5 and also σ, where

$$\sigma=\frac{M}{L_1}$$

The meaning to be attached to the shunt resistance S was, at first, not at all clear. Before the system 9(*b*) was tried, it was expected that the various losses in the system would manifest themselves as an augmented R, and a system such as Fig. 9 (*c*), in which a single resistance R_1 replaced S and R of (b) was at first tried. But the value of R_1 would then need to be variable with frequency, otherwise the value necessary to give the diameter of the circle would be of the order of 20 000 ohms, and the circle would become a spiral starting at 20 000 ohms at frequency=0 and finishing at $R_0=0$ at frequency=∞. When the system (b) was discovered to fit the circle so closely, it became clear that the shunt resistance S must have a physical meaning representing a constant loss in the system for a constant

* A variety of applications of the circle diagram will be found in Dr. Eccles' "*Continuous Wave Wireless Telegraphy,*" Vol. I., Chaps. iii. and iv.

terminal voltage, irrespective of frequency. It is believed by the author that the explanation lies in the nature of the iron losses. The circle has been obtained under the conditions of constant induced voltage of 2 volts on the secondary winding. Now the flux density will therefore be inversely as the frequency, and will in any case be very small. Many measurements made by the author on the total losses in silicon iron at low flux densities and at telephonic frequencies have shown that the main portion of these losses, in the case of sheet material of the usual thicknesses, are eddy current losses. These losses are proportional to n^2 and to $\mathcal{B}^2$. Now, for a constant induced voltage under variable frequency, $n \times \mathcal{B}$ will be constant, and hence the eddy current losses will be constant. The hysteresis losses, however, vary as a power of $\mathcal{B}$ which is greater than 2 at low flux densities (below 100), so that this portion of the losses is not invariable but will increase with diminishing frequency, and it is possible that they appear as an augmented R in the primary winding, or that (together with the small secondary losses) they make up a small total not very variable with frequency or small enough not to be separable from the S term. It must be remembered that in the foregoing analysis R has been tacitly assumed equal to 1000 ohms, *i.e.*, the primary direct current resistance, and then the appropriate S has been determined to make the diameter of the circle come right. If, however, a value of R of 1200 or 1300 ohms had been taken, and the appropriate new S calculated, the new circle would be almost indistinguishable from the old one. The methods under examination cannot therefore separate hysteresis and eddy current losses in the core of the transformer, but they do give an indication of the value of the total losses.

(*To be continued.*)

React...?

By F. Youle, B.Sc., A.C.G.I.

THERE is a growing tendency amongst wireless men to say "reactance" when they mean "reaction." This, although perhaps permissible to the tyro, is a mistake no one who really knows his subject should make, even through carelessness. The novice, accustomed to hearing the two terms used synonymously, is often puzzled when he comes across "reactance" used in its correct sense.

"Reaction," as we all know, is the return of energy from the output of an amplifier (in the wide sense), to the input, where it can be of use in overcoming resistance and increasing apparent efficiency. "Reactance," on the other hand, is the effect of capacity and inductance in a circuit, owing to which an EMF is necessary for the passage of an alternating current.

The man with electrical experience knows that the total opposition to the current in a circuit, called the Impedance, is given by

$$Z = \sqrt{R^2 + \left(\omega L - \frac{1}{\omega C}\right)^2} \text{ Ohms,}$$

where :

R = Resistance in the circuit, in Ohms,
C = Capacity ,, ,, ,, in Farads,
L = Inductance ,, ,, ,, in Henries, and
ω = $2\pi \times$ frequency.

The portion $\left(\omega L - \frac{1}{\omega C}\right)$ is the "Reactance" of the circuit, and is usually denoted by the letter X.

When we tune a circuit, we alter L or C until X=0. It is obvious that for any given values of L and C there is only one value of the frequency which will make X equal to zero, so that for all other values X is a factor which reduces the current, since it increases the values of Z. Hence, when we tune to a station, we are really making the reactance of the circuit zero for that particular frequency, while at the same time it offers opposition to currents of any other frequency. As the value of X at radio frequencies is large compared with R, since ω is then large, this means that signals from other stations will not produce currents great enough to give audible sounds unless they happen to be on approximately the same wavelength.

It is not necessary, therefore, to add anything to a set to enable one to use "reactance." It is there already in the tuning circuits, and it is only by making use of the fact that its value depends on the frequency of the current in the circuit that we are able to tune at all.

To say "reactance" for "reaction" is thus almost as absurd as substituting "black" for "white."

British 2SH.

By F. L. Hogg.

IN these notes it is proposed to give, instead of the usual station details, a résumé of how the particular set in use at present was built, more especially emphasising the methods which were adopted to gain the various ends, and the process of evolution. Special attention will be paid to the mistakes which were made, and similar points. It is hoped that this may be of practical help to those who are rather at a loss to know how to approach the problem of a set which is not behaving itself. I do not mean to say that the methods adopted are the best—in many cases better ideas followed—but they are merely an account of what was done while the set was in construction. What was required was a set capable of operating on any reasonable wave-length from, say, 220 metres downwards, on powers of from 1 kW. to a few watts, which could be adjusted fairly easily for a wave-length change in a short time, for some transatlantic test working at a very reasonable cost. It had to be of a constancy equal to that of the average American relay station, and yet be instantly available for testing almost in any conceivable direction of experimental work. How far these conditions have been fulfilled will be seen.

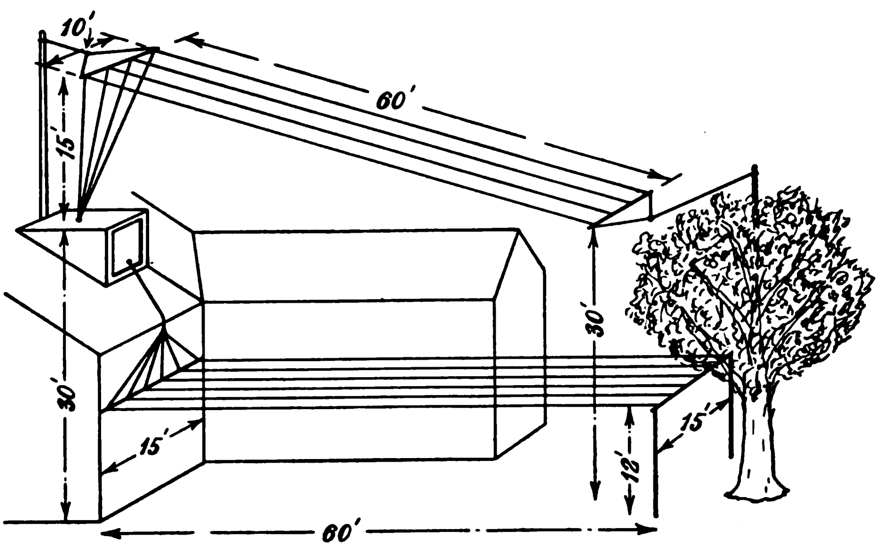


Fig. 1.

Firstly, a description of the aerial system will not be out of place. Unfortunately, this is extremely bad. Fig. 1 shows a sketch of it, giving its main dimensions. At no part of the aerial is it more than 15 ft. from the side of the house or the tree, and the free end is just below the top of the tree. It is impossible to raise either end any further. There is a 20-ft. mast in the tree, but owing to the perversity of the tree the mast only projects five feet above the top, and even then it is none too steady in bad weather. It was also found essential to allow at least five feet sag in the aerial to prevent the wave changing due to the variation in capacity on swinging in the wind. Arranged thus, complaints of wave alteration, even on the shortest waves, have ceased, whereas previously a great deal of trouble had been experienced in this direction. The only redeeming feature is that the station is situated quite near the top of one of the highest points in London. This must account for the extraordinary way in which signals get out. The counterpoise is not at all well fitted up, but limitations of time have prevented this being attended to. It is all right if it doesn't get covered with snow. The lead-in used to consist of a most efficient arrangement. A hole about 4 ft. square was cut in the flat roof, and the wire

led in through this. When it rained a bath was put underneath—affording great diversion to visitors walking across the room. Owing to ultimatums received from the powers-that-be, a 2-ft. porcelain tube, 2" diameter, was fitted in, and this has all the advantages in efficiency without the attendant disadvantages of the old method. Large size Buller insulators are used on the aerial and are perfect in wet weather.

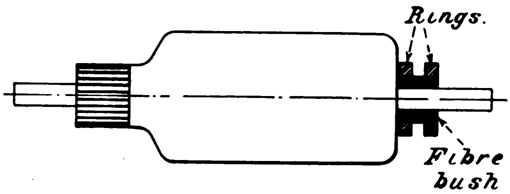


Fig. 2.

To come down to the set proper, the first question was that of H.T. supply Only 240 volts D.C. was available in the house, and it was immediately obvious that the only solution was to use A.C. In considering this, the fact that the set was to be used at night had to be noted, and ultimately it was decided to use a rotary converter of a rather little-used type.

If in any D.C. motor we tap off to two slip rings from two opposite commutator segments, we can take A.C. off these rings on running the motor on D.C. The A.C. voltage is, theoretically, line voltage × ·707, and the frequency, number of pairs of poles on motors × revolutions per second. It will be seen that for a reasonable frequency a high-speed motor must be obtained, and obviously, it must be shunt wound.

After some trouble, a 1 h.p. Siemens 2,700 revolution two-pole motor was obtained and was fitted with rings as follows: At the end of the armature, opposite to the commutator, a fibre sleeve was fixed, about ¼" thick and ¾" long, quite close to the windings, Fig. 2. On this were pinned two rings ½" square section, hole 1", ¼" apart. It was then found on replacing the end plate on the motor that the slip rings had taken up room to the extent that the plate had to be spaced ⅛" from the frame for clearance. Four 3/16" spacing plates were then fitted to the end plate very carefully to give the required extension, Figs. 3 and 4. This made a very satisfactory job of it. The brush holders were fixed in insulating bushes in two adjacent "spokes" of the end plate (see Fig. 5). The brushes are copper-carbon, about 3/16" square. The connections to the slip rings were made from two opposite segments of the commutator. Incidentally, it should be noted that while you can get any number of phases A.C. by using the correct number of rings, the number of segments on the commutator must be exactly divisible by the number of rings. The commutator in question had forty segments. The connecting wires were carefully inserted under the binding wires on the armature, and one passed through a hole in the inside ring to the outer, to which it was carefully soldered, the other being soldered direct to the inner ring. Very soon the insulation burnt off where the wire passed through the other tube, so a small micanite tube was fixed instead. Also the brushes, as originally made, were not quite so strong as those shown in the sketch, and because of the heat developed the sweated part melted and broke off. This was rectified as shown. In practice, on loads up to 100 watts the

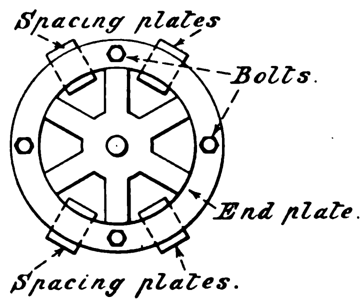


Fig. 3.

voltage curiously is about 190 volts, falling on very heavy load to 140. Theoretically, it should only be 170 maximum. A quite comfortable load is 600-700 watts at 160 volts, and up to 1 kW. can be obtained without making the machine labour. Above 1 kW., though, things begin to happen. It is a very good plan to keep the commutator clean—it makes a big difference to the H.T. voltage. For some time this machine was used during the night just resting on two cushions in the operating room, but now, due to a little wear, etc., it has had to be removed to the cellar owing to complaints! The frequency given by this machine in practice is about 55. This is a most excellent method

Fig. 4.

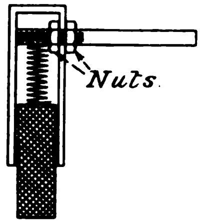


Fig. 5.

for getting a supply of power, for it costs a ridiculously small amount compared with a similar capacity D.C. generator. A small fan motor will comfortably give 50 watts if well made. The next thing to be decided was the valve, and it was obvious that at least one rated at 250 was necessary. Also the question of life had to be considered for obvious reasons. Finally, a Mullard O.250.C was decided upon. The filament consumption is quite high for the emission, and also it has the enormous advantage of being refilamentable for a small portion of the original cost. It takes 12·5 volts 5·5 amps., and has already been in hard use for about six months. It is rated at 2000 volts, but this goes not mean, of course, that that is the required voltage for full output. It was considered that about 3500-4000 volts would be necessary, and the transformer was procured for this purpose. After a lot of trouble an old 90-cycle 2-kW. lighting transformer of the box type was obtained, and was subsequently rewound. The primary was carefully designed and made up to suit—by whom is a question over which there has been some argument, for it was discovered three months later that it was just two and a half times the right size! A secondary was designed and wound by a professional to give 4000 volts, in four sections. The first time the key was pressed the troubles began there. It had broken down from the bottom layer to the core. It did not occur to me that I had earthed the outside (no rectifier was being used). However, after some time the three bottom layers were removed. The set was started up without any rectification to begin with. A filament transformer was made from an old Foster 60-cycle 220-110 volt auto-transformer by removing a few turns to make it suit the line voltage of 160 volts or so, and winding on a secondary of enamelled 7/22 wire to give 15 volts, to allow for any loss of voltage on mains. This was rigged up at first using the inductance shown

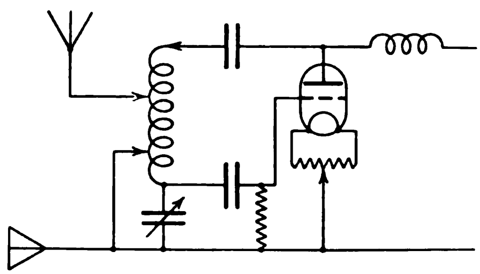


Fig. 7.

in the Colpitts (Fig. 6) circuit for a start, and using full transformer and no rectification; about 200 watts input only was obtained. The water bottle grid leak and anode tap were carefully adjusted for maximum output, and it was found that the coil, which had seventeen turns spaced 1 cm.

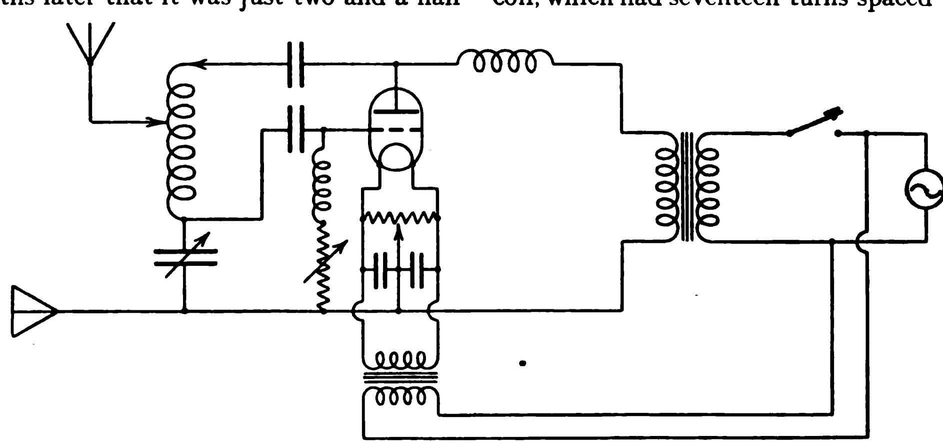


Fig. 6.

on a 45 cm. diameter was not large enough, because the best position was when all the coil was in. Adding a couple of turns made a large difference. The series condenser was a ·0005 set of parts in paraffin, which actually has lower losses than anything else I have succeeded in getting for the voltage !

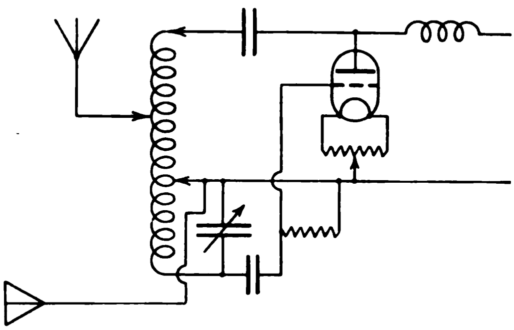


Fig. 8.

The next thing was to try other circuits. The reversed feed-back was tried, but for some reason or other we struck an unlucky patch, for it refused to oscillate on any wave below about 120, and the less aerial coil one used the higher went the wave. This is a phenomenon that happens sometimes, and the best thing to do is to try something else ! So we tried what U1CMK called a modified Colpitts circuit, which gave fine results (Fig. 7). This had been tried on low power before, with a resulting higher input over the normal, so the natural conclusion was that it might help here. The modification consists in taking another connection from the coil between grid and aerial to the counterpoise. It was not noticed for some time that this is really only a Hartley oscillator (Fig. 8) with a tuned grid circuit when it is drawn straightforwardly, and not made to look like a freak arrangement. However, expectations were fulfilled, and the radiation was greatly increased and the input rose to about 300 watts. It was found found that a grid leak was sensitive on radiation to a movement of $\frac{1}{8}''$ either way, and an inch either way would often drop the current one amp. This shows the importance of a finely variable leak. The aerial currents could only be guessed at, as a reliable meter could not be obtained at a reasonable price. The system was to use an old Marconi 0-7 amp. shunted hot wire meter, and add another shunt every time it went off the scale. Now 60 cycles unrectified A.C. is the next worst thing to 25 cycles to read, so a rectifier was started on.

Large numbers of 1-lb. jam jars and a few pounds of lead, aluminium and sodium phosphate were obtained. A bridge rectifier was built with 30 cells in each arm (Fig. 9). The aluminiums were $5'' \times 1'' \times 20$ gauge, and the leads $6'' \times 1'' \times 18$ gauge. These were bolted together at the top with iron bolts. The aluminiums were well cleaned with caustic soda and nitric acid, and fixed up in a semi-saturated solution of pure sodium phosphate. Each cell was formed by placing 240 volts D.C. in series with a radiator lamp across it in the wrong direction. This forms the cells very rapidly. We found with 120 volts on a cell it would pass only about 25 milliamps. reverse current, and this was thought to be all right. It thought differently, for the first time we tried it all the fuses came out. After a bit, by using 1800 volts from the transformer, instead of 3800, we got nearly the same output as before, with a vastly better note. However, the rectifier was really no good, for it took a colossal load even on 60 volts per cell—anything above this brought the fuses out. It was obvious something had to be done about it, so many days were spent forming and reforming the 120 cells without success. The circuit was altered from the bridge to the voltage-raising circuit (Fig. 10), using two 1-μF condensers with improved results. Here 60 cells altogether were used, but it wouldn't take full voltage, even with 120 cells. The only result was that the aerial current went down, and the load up on

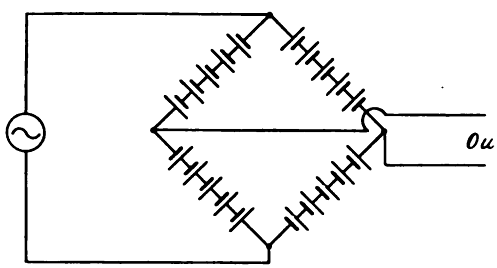


Fig. 9.

increasing voltage. Soon commercial ammonium phosphate was tried, and turned out far worse—having got rid of about ten gallons of the old stuff—and ultimately we got pure phosphate with improved results for a couple of days. Just here came the eventful night of December 8. I had had to test for a couple of hours to get things going

after some changes, mostly on artificial aerial circuit, and when 8AB told 1MO to stand by for 2KF and 2SH, all was bliss and joy—for about ten seconds. Then it all blew up. The rectifier took such a load—about 12 kw., I think—that one of the brushes got completely unsweated and fell off. Just so as not to be unsociable, the transformer blew up again, as it did every few days. That was just about the last straw. It took about four days to get the rectifier to work again, as every one of the 60 cells had to be gone over about umpteen times. The brushes were also reconstructed, as mentioned above. It was by now certain that the trouble was not, as was thought, due to the solution but to the aluminium, so, although what had been in use was bought as the best obtainable commercially, another maker was tried. For all this, results were just as bad as before, so Messrs. Mullard were appealed to and they kindly lent two U250 rectifiers for the job. Incidentally I have recently found that Messrs. Griffin, the chemical suppliers, sell pure aluminium, which is far better than what we used, and at a very reasonable price. Having two perfectly good valves, the next thing was a filament transformer. It was decided to make one, while about it, to stand about 10 000 volts between each of the two secondaries and the primary, so that the voltage doubling circuit could be used if desired.

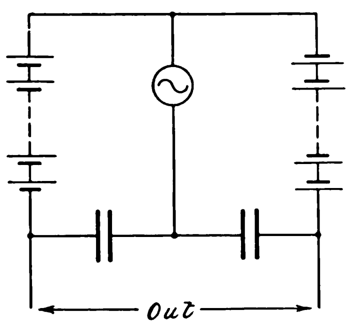
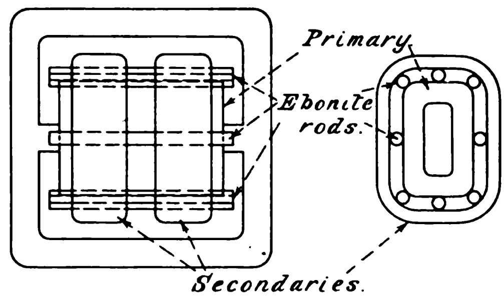


Fig. 10.

This was the method adopted: An old G.E.C. 220-volt transformer, 300 watts capacity, was picked up. The turns were counted and reduced to the required number, found by multiplying original number by $\frac{160}{220}$, and the secondaries wound side by side over this, spaced from the primary by eight $\frac{1}{8}''$ ebonite rods at the corners and middles of the sides. This is shown in Figs. 11 and 12. The secondaries had to supply 10 v. 3·5 a., but because of the spacing between primary and secondaries they are designed for 16 volts, which is just enough. There have been many attempts to blow this up, but all have been unsuccessful. It was clamped up with ever-useful Meccano strips instead of the usual shell, for safety's sake. It can be



Figs. 11 and 12.

seen between the rectifying valves. These were mounted roughly close at hand and put on instead of the chemical rectifier with exactly the same voltages, etc. (Fig. 13). The radiation went up a little, which was a good sign. It was found using this doubling circuit that it was essential to adjust the filaments to a very fine degree. The usual split transformer circuit was tried, but results were absolutely no use, as the two halves of the transformer were unequal. It was also found that the wave was extremely sharp owing to the smoothing the condensers provided, so this circuit was kept in use despite warnings that surges would be troublesome. Now the transformer voltage was increased—for a few minutes only. The radiation went off the map, but so did the transformer. However, this was put right soon; and then the condensers began. It was found disastrous in many ways to have large slabs of condenser flying around the room, accompanied by a colossal noise in the middle of the night, so four were placed in series instead of two. Well now, the input, despite the greatly reduced primary turns, could on occasions reach 400 watts or so, and 350 or so could be got always when required. However, the good work was carried on by reducing the primary turns. Result—more condensers and turns off the secondary till we arrived just where we started! It was highly amusing—for everyone but the owner—when every time a condenser blew a surge was produced which

made a large flash inside the vacuum of the oscillating valve between one of the plate supports and the filament spring. It at any rate showed that the insulation was excellent elsewhere, as about 15 000 volts are necessary to do this! Thus things went on until one of the rectifier filaments went—due to over-running it, as no maker will put an A.C. filament voltmeter on the market at a

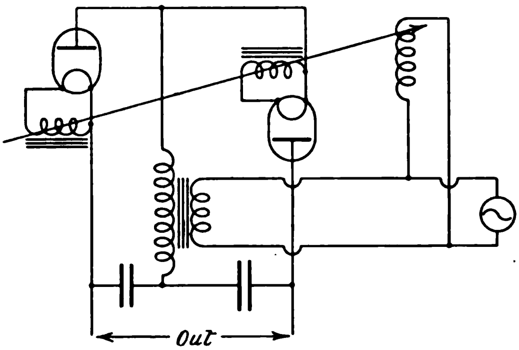


Fig. 13.

reasonable price. Then the set was worked again unrectified. The result was not so much a lost radiation but a terrible note to read through any interference, and all Americans came back "QSA BT QRM QRN," so one-third of the radiation was lost by putting in a single-valve rectifier and a bit of a choke and ½ mfd. across the line—in the correct way so as not to build a filter. However, this improved results to an extraordinary degree. Here the transformer finally turned over and died, so an old Marconi pack set spark transformer, 75 volts 175 cycles 500 watts, was re-wound on the primary and put in for want of anything better. Apart from taking a no-load current of about 3-4 amps. this works very well if more than 100 watts is not wanted! What is in use at present is this transformer with the two rectifier valves paralleled. This gives a radiation of quite reasonable value with a passable note. This completed the H.T. episodes! The voltage obtained on a load of 120 milliamps. or so was just about the transformer voltage. That is, the doubling device had made up for all losses in the rectifier. The H.T. maximum obtained for any time worth considering was 3200 volts, and it became obvious that a 6000-volt transformer would be necessary to get full output. This will be done when a little time is available!

During this time many circuits, freak and otherwise, were tried. Always, however, best output was obtained on the tuned-grid Hartley. It was found, as others have discovered, that at a point of maximum radiation the set is liable to flop over on to another wave-length. This was found to be due to the fact that almost invariably best results are obtained on this circuit when the grid circuit is tuned to the second harmonic of the aerial circuit. Incidentally this circuit puts out a large harmonic anyway if care is not taken. By adjusting taps very carefully this can be avoided and the flopping-over reduced to a great extent. This circuit is by no means easy to adjust, and so a few details will be given. Suppose you have a coil which, using Colpitts, requires for a given wave plate and grid to opposite extremities and aerial at the mid point between the two. Now take the wire from the earth and tap this on a turn about one-third of the way between grid and aerial. Then tune the condenser and note results. If the radiation is best on minimum condenser, decrease turns between grid and earth, and so on. Then, supposing you are aiming at 200 metres, you, having got things fairly tuned up, find you are on about 101 or 370 metres. The next thing is to start again with less aerial turns, and so on. One can amuse oneself for hours this way until one gets used to the set. Having discovered an efficient point, try altering the grid-leak—it helps a lot and probably will alter all the tappings you have laboriously found. However, having found

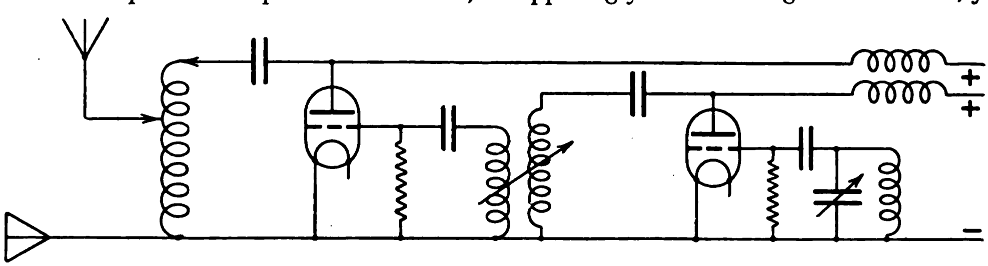


Fig. 14.

good results, make a careful note of the settings for future reference.

Best results as regards output on a given voltage were obtained from the master oscillator, but unfortunately the H.T. troubles stopped much in this way for permanent use (Fig. 14).

connection from the condenser to the grid was removed and made variable on the coil. This gave better working at once. Then a series aerial condenser was tried (another ·0005 set of parts, now immersed in paraffin). This helped further and it was found that the two condensers and the aerial tap served

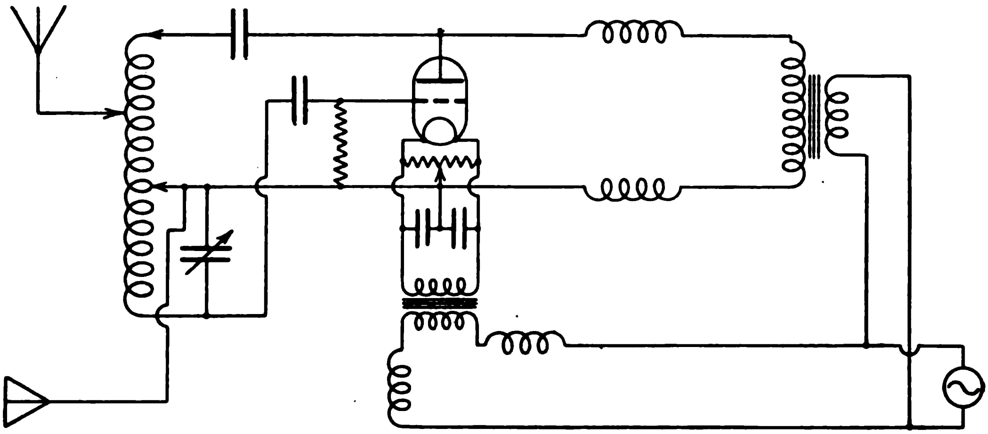


Fig. 15.

During this time, of course, it had become necessary to drop to 100 metres, and here further fun began. The taps on the tuned-grid Hartley were carefully lowered by slow degrees from 180 to 135 metres. All was beautiful, radiation exactly what was expected, but—just a touch more and nothing would happen, in comparison. On 134 metres the radiation dropped to about one-fifth of the previous value. Colpitts was then appealed to. Results were exactly the same. It soon became obvious that absorption somewhere was the trouble. After nearly every imaginable absorbing body had been searched for, a radio-frequency choke was placed in the negative H.T. lead. The result was that it would now go down to about 132 metres, which indicated that we were on the right lines. The brain-wave was then conceived of trying chokes in all power leads, so two were placed in the filament transformer leads. The result was that immediately we got down to 100 metres easily. (Fig. 15). It was found no joke using the tuned-grid Hartley on that wave (of course a series aerial condenser was used below 160 metres), so Colpitts was tried. Results here were good up to a point, but it was not very good below 120 metres, so a little dodge was tried. The difficulty was mainly that altering the aerial turns did not alter the wave-length as it should. The

more as fine adjustments for wave-length and governed radiation while the condenser tap altered the wave-length. After a lot of juggling about the expected results were obtained and this circuit is still used. (Fig. 16.) Now next time we went up to 200 metres the set was all over the place. The r.f. chokes spoilt everything. On the low wave the trouble was that the capacity between the windings of the transformers was serving as a series condenser in between the counterpoise and the earthed mains forming a tuned earth very much out of tune.

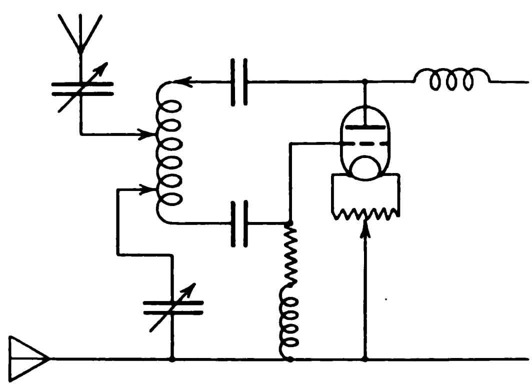


Fig. 16.

Still, this did not explain the extraordinary results, and many hours were spent trying to tune the mains; but they wouldn't be tuned

anyhow. Many days after it was discovered that an old buried earth—or rather three—had been connected to the mains through a 2-mfd. condenser under the table. This of course explained the extraordinary effects. All these five earths happened to more or less "fit" round 200 metres, one compensating for the other, but on the lower waves this was not so. This has been shown to be true, but due to the usual reason it has been impossible to rig up a proper arrangement as yet, for this is sure to improve results. Beyond these points there was no difficulty in getting down quite low—even to 90 metres. The anode tap is most critical, however, and must be carefully watched, for one turn too few will sometimes stop the set oscillating. The troubles of about 90 per cent. of amateurs in getting down very low are due to some effect in supply wires and I can thoroughly recommend attention to this point. This about completes all the adventures with the transmitter.

The receiver uses the ordinary tuned anode circuit with ORA valves normally, but on 100 metres a C300 soft detector (which survived a journey by post from California) is used. This valve gives marvellous signal strength, but it is useless on 200 metres if there is any QRM at all, owing to the damping produced by grid current. Signals on 200 metres are half the strength and ten times in number from the States on an ORA! If the soft detector gets better distant signals they are always jammed out, and if a sufficiently more selective set, to make up for the loss in selectivity, is used the advantage in distance is lost. A super-heterodene is available, but has not been used greatly for several reasons. It gives marvellous results on many signals: the Tate sugar box under the receiver is the motor starter. A 50-ohm resistance with tappings is hung across inside. All other parts need no comment. As is obvious no trouble has been spent on appearance—all the available time has been taken up in making things work.

Fig. 17.

As to results, the first report of signals from the States was received only fairly recently, referring to September 21 last when a temporary set using 500-cycle I.C.W. was in use for a couple of days putting out only 1·5 amps. on 185 metres. This was heard by 8OX, and reported by card to American 2SH, who after some time replied that he had no set. Suddenly 8OX realised who

it was, and the report has now been confirmed properly. This seems the first occasion on which any British station has got across using a power which was really less than 1 kW. The next report was from 2BL on November 25, at about 0030 GMT. Next came the best ever—one from 5XD, New Mexico, 500 miles from the Pacific coast, who heard signals for several minutes and read what was sent, on December 1. by 9CD of Chicago and probably even further inland. The small current was of course due to the troubles already mentioned above. Since then, radiation gradually improving, a number of stations have been worked. 2AGB was worked a very large number of nights, and almost invariably received without aerial or earth. At the times at which really high power has been used, the strength was reported to be greater

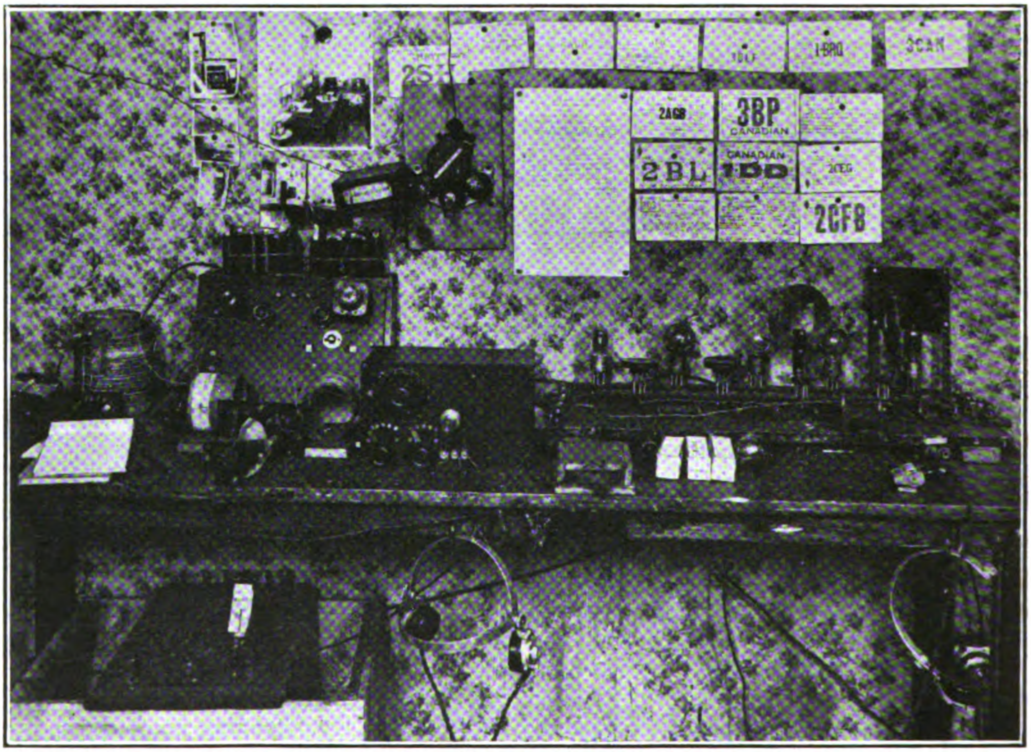


Fig. 18.

than that of 8AB: but, not so much because of the H.T. troubles, but because the P.O. graciously permitted a lengthy transmission on over 100 watts for 15 minutes per night, it was not felt to be worth while to use high power to any extent. No useful results of the kind which are being worked for can be obtained with such a ridiculously short time limit, it being far better to keep things constant at 100 watts. Finally, almost 2 amps. were obtained on 100 watts and 3·5 to 4 on maximum power (that is maximum in use for any time. Sometimes 700-800 watts were obtained until that loud noise you heard happened !) The efficiency is not

Since this little has been done on 200 metres. In the organised tests only six 10-minute schedules were transmitted. One of these was heard in Georgia. Interference from GKB has now stopped any serious 200-metre work, as he rarely closes down now except for a few minutes during the night. The radiation in these cases was 3·5 amps. on 100 watts input. This was only measured a few weeks ago by a borrowed meter, but results had been noted as readings on the meter used. This applies also to the following readings. On 100 metres 1XW was worked on December 12 with about 75 watts and ·65 amp. in the aerial ! This was heard

nearly so high as it should be, but the work has had to be done in very short periods and work can only be done on very few days per week, so the set could be greatly improved in detail. Altogether 16 stations have been worked, including 4BZ of Atlanta (on 1·2 amps.), the best distance, and 9AZX of Indiana, half an hour after daylight here. Now considering this carefully, we have a terrible aerial system and a medium power set and yet the results are astounding. It all goes to demonstrate how little is really known about 200 and 100-metre working. No credit can be claimed for results at all, and considering the time of operation which has been only about a quarter of that of many others, results would not be bad for a real 1 kW. on an aerial worth the name. The only thing seems to be the undoubtedly favourable situation of the station. Anyhow, the whole thing seems rather contradictory; for on 100 watts, say, signals are the same on the coast or inland and on higher powers the strength is only greater at the coast. Which all goes to show what has already been said, that the sooner we learn something about 200 and 100 metres the better!

I hope these notes will help some of those who have written to me as regards the methods to be adopted to get things going. It is, of course, a matter of opinion always, and this merely gives things as they appealed to me, whereas they will appeal to others in different ways. But when one has not had sufficient experience to have formulated opinions it is extremely bewildering. If these notes stop a few writing and asking "why won't it work," by helping them to see their difficulties, it is quite sufficient.

I should like to acknowledge my indebtedness to Mr. Robinson, 2VW, well known to EXPERIMENTAL WIRELESS readers, for his most valuable help—for many pleasant (?) hours spent over rectifiers and the like!

Amateur Wireless in Australia.

IT is thought that a few notes on experimental activities in this part of the world may be of interest to British experimenters, particularly in view of the excellent DX work that is now being achieved.

From the earliest days of wireless telephony there has been a limited number of experimenters in Australia, but only during the last three or four years has this science achieved any measure of success. In particular, the advent of the valve, together with the issue of experimental transmitting and receiving licences, has done much to stimulate amateur activities. Shortly after the conclusion of the war the issue of receiving licences recommenced; one or two amateur transmitters were also allowed to operate on low power under special licence. However, it is only during the last two years that amateur transmission has been allowed on any considerable scale.

Under the present regulations, experimental licences (as distinct from those for broadcasting) are granted either for transmission and reception, or for reception only, the fee being £1 for the former, and 10s. for the latter, payable annually. Applicants have to state the nature of the experiments it is proposed to conduct, produce evidence of satisfactory technical qualifications and, if necessary, must submit to a technical examination in writing; they must also pass an examination in Morse transmission and reception at 12 words per minute.

Transmitting licences are not easy to obtain; they are granted only after careful investigation by the Government officials, and definite experimental work of value to the science must be undertaken. Within five miles of a commercial or defence station, no spark transmission is allowed, and the input of valve transmitters must not exceed 10 watts. Up to 50 miles from commercial stations, any system of transmission is allowed on power not exceeding 25 watts, and at greater distances 250 watts is permitted. Each experimental transmitter is allotted a definite wave-length, in the band ranging from 100 to 250 metres, and may not deviate from this wave without special permission. There are about 300 licensed amateur transmitters in Australia at the

present time, and a considerable number in New Zealand.

Conditions for reception and transmission in Australia and New Zealand are, generally speaking, very good—better, it is thought, than around the British Isles, though in the summer atmospherics are much stronger and more prevalent than in England. In fact, X's often becomes so severe that ship and shore traffic is paralysed for hours at a time; but, as usual, less trouble is experienced on the shorter amateur waves.

Reception in New Zealand is remarkably good, equalling if not excelling that in any other part of the world. The leading New Zealand amateurs, with comparatively straightforward receivers, have repeatedly copied signals from every American amateur district in a single night, although the distance involved may be anything from 6000 to 9000 miles; American amateurs have been frequently copied on a single valve. One New Zealand experimenter claims a world's record for broadcast reception on one valve, having heard and verified a transmission from WHAZ at Troy, New York. The distance is some 9,000 miles.

In general, circuits and apparatus used follow British practice in reception, and lean rather towards American methods in transmission. The majority of the more successful receiving stations employ one or two stages of H.F. amplification, using either tuned transformer or tuned anode coupling, and English valves are very generally used. It is noticeable that H.F. transformers for amateur waves are usually wound with much heavier wire than is commonly used in England, 22 gauge wire on a three or four inch former being common. Tuned anode receivers are frequently stabilised by the introduction of a variable high resistance in series with the plate circuit, or a lower variable resistance in series in the rejector circuit itself. Australian practice differs from British in one notable respect, much greater use being made of the soft and semi-soft valves as rectifiers; and much of the unusual reception must be attributed to this. Valve receivers capable of oscillating the aerial are not permitted.

The long distance single valve receptions previously referred to were all accomplished with soft valves. It has often surprised the writer that British valve manufacturers do not pay attention to this type of valve, for good specimens would have a great sale among experimenters once their remarkable capabilities became known. Undoubtedly the very critical adjustments of filament and plate voltage necessary for good results deter many people, but such difficulties can easily be surmounted. The American Audiotron, a tubular valve no longer manufactured, was probably the most sensitive valve ever commercially produced, and a few Australian experimenters still have carefully preserved specimens, which are highly prized, as much as £5 being offered for one. It is understood that the reception of WHAZ previously mentioned was accomplished with one of these valves. One soft valve of fair quality is manufactured in Sydney, and is used extensively in commercial service; the semi-soft American, UV200, is also much used by amateurs.

In transmission, the American 5- and 50-watt Radiotrons are used more extensively than any others, and the 5-watters in particular have accomplished some remarkable D.X. work. Using only one of these valves, experimenters carry on excellent two-way communication between the capital cities of Australia, on both c.w. and voice, though the distance is never less than 500, and often in the neighbourhood of 1,000 miles. Reliable communication is also obtained on similar power between Australia and New Zealand, the distance varying from 1,200 to 2,000 miles, and complete musical programmes have often been successfully received under these conditions. Good communication has actually been established between Australian 2CM and New Zealand 4AA on an input power of ·0037 watt. The input was checked and certified by independent witnesses, and on this power complete messages were received in New Zealand, a distance of over 1,200 miles. It will be seen that the Australian transmitting amateur has little to learn from other countries in point of efficiency; it should be noted, however, that no restriction is laid upon the dimensions of our aerials.

Tuned counterpoise is almost universally used in conjunction with the usual earth, and the reversed feed-back circuit is very popular. Filament supply is usually A.C. and plate supply rectified A.C. or, less often, high-voltage D.C. Constant-current (choke-control) modulation is usual, but much excellent work has been done on grid modu-

lation; many have also had great success with absorption modulation, obtained by connecting a microphone in series with a loop of one or two turns, and placing the loop in inductive relation with the A.T.I.

A unique experiment has just been carried to a successful conclusion and has provided data of great value to Australasian experimenters. Mr. Maclurean, of Sydney, who operates 2CM, obtained permission to instal a duplicate of his transmitter and receiver on a trans-Pacific liner, and make the voyage to America, in order to ascertain how far it was possible to maintain communication on amateur wave-lengths and power; and incidently to discover why American amateurs are unable to receive Australia, while Australians log innumerable American stations.

With 8 watts input at the Australian end, messages were copied up to a distance of 5,380 miles—two days' voyage from San Francisco. On the same set, using 4 valves, music was received clearly at 4,300 miles on a loud speaker—not bad for 8 watts input! Closer to America, indescribable QRM from American amateurs rendered consistent reception from Australia impossible; nevertheless, messages were copied from a 100-watt transmitter in Sydney at a distance of 5,900 miles, and calls from both the 8-watt and 100-watt sets were actually heard at good strength whilst lying in 'Frisco, over 6,000 miles away. Code messages could not be deciphered through the local jamming.

The 10-watt transmitter on the liner was unfortunately put out of action early in the

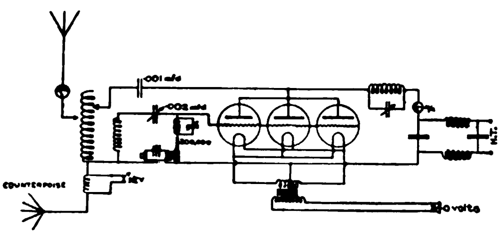


Fig. 1.

voyage, so that two-way communication at extreme ranges was impossible. KGO was heard strongly on a loud speaker at 5,600 miles, being audible all over the ship's afterdeck. KGO is, of course, the American broadcast station at Oakland, California.

The receiver employed was a four-valve set, employing 1 stage tuned anode and 2 stages L.F. amplification, and a three-coil tuner. The H.F. valve was a Marconi QX, the other three being American 201A Radiotrons, which closely resemble the B.T.H. B4 type. No grid-leak was used on the rectifier. Fig. 1 is the circuit diagram of the 8-watt set which was used at the Australian end (I am endebted to "Radio," for this). It will be seen that a counterpoise only was used. The aerial was a 100 ft. T-type on an 80 ft. mast; a 6-wire 4 ft. cage construction being used. The transmitter was supplied with 7-8 watts of rectified and smoothed A.C. and gave an aerial current of 1·8 amps. at 235 metres. For music, speech and I.C.W. grid modulation was used.

[Note.—There seems something doubtful here. Even assuming an efficiency as high as 83 per cent. for the transmitter, only 6·5 watts are available for output. With 1·8 amps. this gives 2 ohms as total effective aerial resistance, which seems to us extraordinarily low. In view of the ranges covered, we are inclined to believe that the input quoted (7·8 watts) is under-estimated.—Ed. E.W. & W.E.]

In conclusion, it may be mentioned that the regulations under which experimenters have hitherto worked are now being entirely recast, and if, as is hoped, greater latitude is given in the matter of power and wavelength, and the American amateurs can learn to handle H.F. amplification properly and to control their local QRM, two-way working between Australia and America can confidently be expected in the near future; direct communication with England also seems quite possible under favourable conditions. May it be soon!

Further Notes on Resistance-capacity Amplification.

By F. M. Colebrook.

Giving details as to the design of such amplifiers for L.F. work, for which they are becoming increasingly popular.

THE resistance-capacity type of inter-valve coupling appears to be gaining steadily in popularity, both for high frequency and low frequency amplification. Its characteristics have been the subject of a considerable amount of research work during the last few years and the following references may be of interest.

In an article by the present writer, published in EXPERIMENTAL WIRELESS in March, 1924, it was shown that the howling effect frequently experienced with resistance-capacity coupled amplifiers is probably due, not to a genuine low frequency oscillation, but to the periodic starting and stopping of radio frequency oscillations in the input circuit. It was further shown that this troublesome tendency could be eliminated with very slight loss of efficiency in operation by the use of grid leaks of lower resistance than had hitherto been customary, about ½ megohm being a suitable magnitude in most practical cases.

A very complete analysis of the inherent reactive effects and the stability conditions of radio-frequency resistance amplifiers was given in two articles by M. Léon Brillouin published in *L'Onde Electrique* in January and February, 1922. It is there shown that the phase relationships of the various potential changes occurring in different parts of the amplifier are the vital factor in determining the stability or instability of the input circuit—amplifier combination. The limitations of amplifiers of this type for short wave-lengths were considered by the same writer in association with M. Beauvais in an article published in *L'Onde Electrique* in May, 1923. It was shown in this paper that by the careful constructional minimisation of accidental capacities and the use of valves of low inter-electrode capacity, the useful range of a resistance amplifier could be extended very considerably in the short wave direction, even down to wave-lengths of only a few hundred metres.

Recently a certain amount of attention has been paid to the question of low frequency amplification by means of resistance coupling. It is generally agreed that a purer reproduction can be obtained by this method than by any of the available alternatives.

On the occasion of the opening of the British Empire Exhibition at Wembley, the writer was able to make an interesting direct comparison between the results obtained by resistance-capacity and low frequency transformer amplification. At either end of a fairly large hall two receiving sets were working simultaneously, operating two loud-speakers of the same make. The distance from 2LO was about twelve miles, and each set was connected to its own aerial. One of the sets was a straightforward arrangement of detector valve and two low frequency transformers, the transformers used being of very high quality judged by present standards. The other set consisted of a crystal detector and a three stage resistance-capacity coupled amplifier, the circuit being as shown in Fig. 1.

The difference between the two reproductions was very marked indeed. The transformer set gave very much greater intensity, but the quality was poor. It is no exaggeration to say that the following of the speeches called for considerable concentration on the part of the listeners. The resistance set, on the other hand, gave very clear articulation and a reproduction that was easily intelligible.

Simplicity of operation and purity of reproduction are very desirable features in any arrangement intended for the reception of telephony. The circuit shown in Fig. 1 possesses both these characteristics, and it may therefore be of interest to consider in fuller detail some of its special features.

The input circuit is worthy of note. It will be seen that the aerial is tuned by means of a series condenser and an inductance, the crystal detector being in shunt to a part only of this inductance. A simple experimental account of this point was given

by the writer in an article in the *Wireless World* on April 30th.

A perikon detector was used, since, as shown elsewhere by the writer[1] this is superior to galena for use in connection with valves or with circuits of very high impedance.

It will be noticed that the low frequency impulses in the crystal circuit are stepped-up on to the input of the amplifier by means of a low frequency transformer. This may appear to be wasting the distortionless character of the amplifier by introducing distortion right at the outset. Such is not the case, however. It is well known[2] that the principal cause of the distortion produced by a low frequency transformer is the variation with frequency of the ratio of the primary impedance of the transformer to the internal resistance of the valve in the anode circuit of which it is used, the greatest magnitude of this ratio being, in most practical cases, in the region where its variation is most likely to be harmful. The conditions under which the transformer is used in the present circuit are quite different from this. The impedance of the transformer winding is so much higher than the resistance of the crystal that the case approximates to that of pure potential rectification and this type of rectification is practically free from distortion.[1]

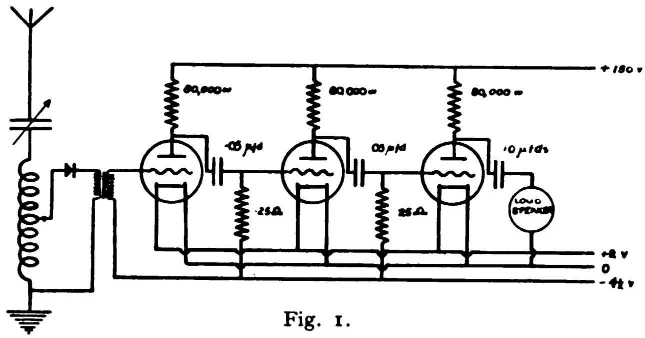


Fig. 1.

The only distortion likely to be produced by the transformer in the circuit illustrated is that due to the variation of its transformation ratio with frequency, which variation is, in general, too small to cause any noticeable effect. It is here assumed that there is no appreciable load on the secondary of the transformer. This condition is essential,[3] and is easily ensured by applying to the grid of the valve a negative potential of such magnitude that the oscillating signal potential will not at any time make the resultant grid potential positive, the anode potential being of a suitable value to correspond to this applied mean grid potential. With the D.E.R. valves used it was found that a total high-tension of 150 volts with a negative grid potential of 4½ volts appeared to be quite satisfactory. It should be pointed out that the transformer is not essential to the circuit. Under suitable conditions of distance, aerial resistance, etc., quite sufficient intensity can be obtained without it, the detector being connected directly to the grid as shown in Fig. 2. The writer made these two arrangements interchangeable by means of switches, and found that the transformer gave a marked increase in intensity without apparent detriment to the quality.

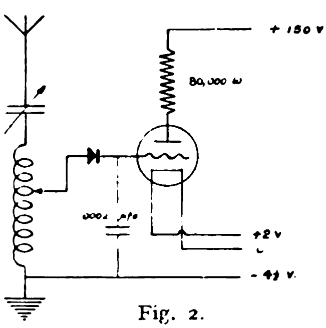


Fig. 2.

The method of connecting the loud-speaker to the last valve should be noted (see Fig. 1). It has two advantages. In the first place, it avoids what would otherwise be the necessity for a separate high-tension tapping for the last valve, allowing for the difference between the d.c. resistance of the loud-speaker windings and that of the anode resistances in the preceding valves. The second advantage is that in the arrangement shown the continuous anode current does not flow through the loud-speaker.

In any type of resistance-capacity coupled amplifier the suitability of the anode resistances used is a very important factor. Of the various types at present on the market, some, no doubt, may be quite satisfactory. The writer, however, has not been altogether fortunate in his experiences with such products. In spite of every care with contacts he found it impossible to eliminate entirely a certain crackling or rushing noise in the telephones. The anode resistances then being used were therefore examined by being inserted in a Wheatstone bridge circuit with

a very sensitive galvanometer. It was found that, even when the potential differences across the resistances were considerably less than those which would occur in practice, the galvanometer indicated not only a steady decrease in resistance, but also slight spasmodic variations in resistance such as might arise from contacts of a microphonic character. It seemed probable that this might be the cause of the extraneous noises heard in the telephones. It was decided, therefore, to substitute resistances made with high resistance wire. When this change was made the stray noises disappeared and the amplifier was absolutely silent in operation.

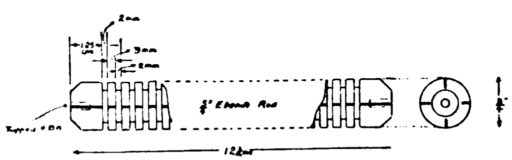


Fig. 3.

For the special experimental purposes to which the amplifier was originally applied it was necessary that the resistances should be non-inductive. For general purposes this may not be quite so essential, though in most cases it will be desirable, in order that the resistance shall not vary appreciably with frequency. Further, for high frequency amplification it is essential, and for low frequency amplification desirable, that the self capacity of the resistances shall be as low as possible. Judging by the results obtained the type of construction now to be described fulfils both these requirements in a satisfactory manner.

The former on which the resistance wire is wound is as shown in Fig. 3. It consists of a length of $\frac{3}{4}$in. diam. ebonite rod cut with 20 equal and equidistant grooves. This, of course, can be done quite easily on a lathe. In addition, there are four narrow longitudinal slots, equally spaced round the diameter and cut to the same depth as the grooves. These were put in with a milling cutter, but they could be made with a fine hack-saw without much difficulty. Finally, the ends are chamfered and the centre of each end drilled and tapped with a 4 B.A. hole.

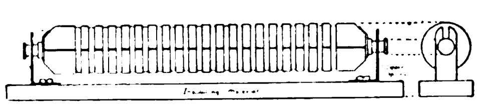


Fig. 4.

The wire used is 47 S.W.G. double silk covered Eureka. The method of winding is as follows : the former is mounted in a lathe between a chuck and a back centre, and 50 turns are wound into the first groove, the end of the wire being left projecting for connection. The wire is then led through one of the longitudinal slots into the next groove and 50 more turns wound on in the same direction. It is again led back through another slot into the first groove and 50 turns wound in the reverse direction, then back into the second groove for 50 more turns, also in the reverse direction. The process is continued until 300 turns have been wound into each of the first two grooves. The wire is then led through a slot into the third groove, and this and the fourth are filled in precisely the same manner. The process is continued until the whole of the grooves have been filled with 300 turns each, there being in each groove 150 turns in either direction. Finally, the ends of the wire are soldered on to small copper tags held in position by 4 B.A. terminals screwed into the ends of the former, as shown in Fig. 4 (which also illustrates a convenient method of mounting the finished resistances).

The resistance of a single unit made as described above will be found to be about 60 000 ohms. Any other desired value can be obtained by a suitable modification of the dimensions. The constants of the wire are as under :—

Diameter over insulation	..	·004 inches.
Resistance/1000 yds.	..	214 000 ohms.
Weight/1000 yds.	..	·036 lbs.

The wire is, of course, expensive, the present price being about seven shillings an ounce. As will be seen from the above figures, however, only about an ounce and a half are required for a 60 000 ohm unit, so the total cost compares favourably with that of a low-frequency transformer.

No special merit attaches to the figure 60 000 ohms, and where high-tension is not a limitation this can with advantage be increased to 80 000 or so. Resistances of this value can easily be made with the same overall dimensions as described above. A set of resistances of this magnitude was in fact constructed by the writer, and was used in the circuit illustrated in Fig. 1.

The proper choice of the value of the inter-valve condensers is a matter of considerable importance, for on this will depend the uniform behaviour of the amplifier with respect to frequency. This condenser serves no useful purpose in the amplification process proper, and its only function is to prevent the continuous anode potential of any one valve from acting directly on the grid of the succeeding valve.

It is obvious that there is a certain loss of voltage over this condenser and that this loss is greatest at low frequencies. It may be shown (see Appendix) that if f is the lowest frequency we wish to consider, and that we decide on a maximum loss of voltage to be allowed, *i.e.*, a minimum ratio of E_g to E_a in Fig. 5, then the smallest capacity which we may use is

$$C = \frac{n}{2\pi f R} \mu F$$

where R is the grid-leak resistance in megohms, and n is derived from the curve in Fig. 6.

Suppose, for instance, that the variation with frequency over the whole audible range, from 50 cycles upwards, is not to exceed 3 per cent. The curve of Fig. 6 shows that in order to fulfil this requirement the lowest value of n shall not be less than 4. We have, therefore,

$$C = \frac{n}{2\pi f R} = \frac{4}{2 \times \frac{22}{7} \times 50} \times \frac{1}{R}$$

$$= \frac{\cdot 0128}{R} \mu F$$

The requisite value of C depends on that of R. For reasons already given, a suitable value for R is about ·25 megohms. In this case we have

$$C = \frac{\cdot 0128}{R} = \frac{\cdot 0128}{\cdot 25} = \cdot 05 \ \mu F \text{ approx.}$$

With intervalve capacities of this magnitude, the overall variation of the amplification with frequency for a three stage amplifier will not exceed 6 per cent. over the whole range of audible frequencies from 50 cycles upwards, and from 100 cycles upwards the variation will not exceed 2 per cent. This degree of constancy is superior to anything obtainable with low-frequency transformer coupling.

It may be argued that since a larger value than ·05 μF for the intervalve capacity would give an even greater constancy with respect to frequency, there is no reason why a larger valve should not be used. In practice, however, there is really nothing appreciable to be gained by doing so, and the use of capacities larger than are actually necessary is undesirable for reasons of economy, low dielectric losses, high insulation, quickness of response, etc.

There is one other detail in connection with intervalve condensers, whether for high or low frequency amplification, the great practical importance of which is not sufficiently realised; namely, the necessity for very high insulation resistance. The consequence of any imperfection in this respect is that a certain proportion, not necessarily the same in each stage, of the continuous battery potential on the anode of any one valve is passed on to the grid of the succeeding valve. Suppose, for instance, that the continuous anode potential of one valve is 50 volts, that the grid leak resistance is 2 megohms, and that the insulation resistance of the coupling condenser to the next valve is 25 megohms. It is easily seen that the insulation resistance of the condenser and the resistance of the grid leak form a sort of potential divider, and that a positive potential of approximately 4 volts is added to the applied negative grid potential of the succeeding valve. This is quite sufficient to modify its behaviour very considerably. It is an additional advantage attaching to the use of grid-leaks of comparatively low resistance that they will greatly reduce the detrimental effect of defective condenser insulation. Thus, in the case considered, if the grid leak resistance is only ·25 megohms instead of 2 megohms, the positive potential passed on to the grid will only be a half of a volt instead of 4 volts.

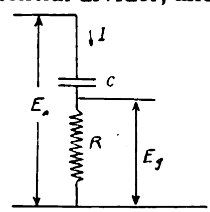


Fig. 5.

Due attention being paid to the matters of detail enumerated above, it will be found that resistance-capacity low frequency amplification is exceedingly satisfactory from the point of view of ease of operation and purity of reproduction.

Appendix.

The principal requirement to be fulfilled by the capacity is that its impedance at the lowest important audible frequency, say 50 cycles per second, shall be small compared with the resistance of the

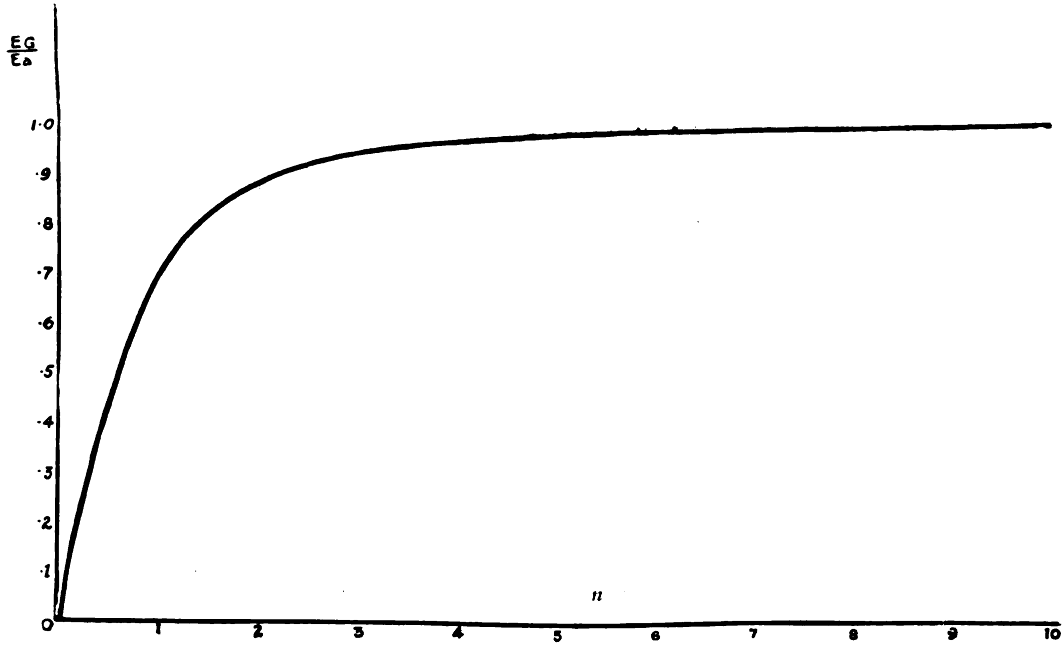


Fig. 6.

grid-leak. Referring to Fig. 5, if $\mathbf{E}_a$ is the vector alternating signal potential difference produced at the anode of any valve of the amplifier, its frequency being $\omega/2\pi$, then there will flow in the circuit consisting of the grid condenser and the grid-leak of the next valve a current given by $\mathbf{E}_a/Z$, Z being the impedance operator of the capacity and resistance in series, *i.e.*,

$$Z = R \times \frac{1}{j\omega C}$$

$$= \frac{1 + j\omega CR}{j\omega C}$$

The vector representing the current is therefore given by

$$\mathbf{I} = \frac{j\omega C\mathbf{E}_a}{1 + j\omega CR}$$

If $\mathbf{E}_g$ be the vector representing the alternating potential difference produced across the grid leak, *i.e.*, the potential difference which is applied to the grid of the next valve, then

$$\mathbf{E}_g = R\mathbf{I} = \mathbf{E}_a \frac{j\omega CR}{1 + j\omega CR}$$

The corresponding equation relating to the amplitudes or root-mean-square values of these potential differences is therefore

$$\frac{E_g}{E_a} = \frac{\varpi CR}{\sqrt{1 + \omega^2 C^2 R^2}}$$

or, putting n for ωCR,

$$\frac{E_g}{E_a} = \frac{n}{\sqrt{1 + n^2}}$$

This expression, $n/\sqrt{1+n^2}$, is clearly a factor by which the theoretical voltage amplification given by any particular valve is multiplied in consequence of the coupling conditions. It is important, therefore, that this factor should vary as little as possible with frequency. This is particularly the case where multi-stage amplification is concerned, for a little consideration will show that an $m\%$ variation with frequency of this factor in each stage of an r stage amplifier will cause an overall variation of $(r-1)m\%$ with frequency in the total amplification. This is a feature common to all multi-stage amplifiers and its importance is not always realised.

The variation of $n/\sqrt{1+n^2}$ with n is shown is Fig. 6. Its chief characteristic is its extreme flatness for the higher values of n. This means that the variation of $n/\sqrt{1+n^2}$ with frequency can be reduced to any desired extent by fixing a suitable minimum value for n.

[1] "The Rectification of small Radio-Frequency Potential Differences." F. M. Colebrook, *Wireless World*, April 30, p. 122.

[2] "The Conditions for Distortionless Low-Frequency Amplification." F. M. Colebrook, EXPERIMENTAL WIRELESS, May, 1924.

[3] "Grid-Filament Conductivity: Its Effect on Amplification." F. M. Colebrook, *Electrician*, November, 1923.

A Combined Test and Broadcast Receiver.

Details of a receiver designed to fulfil a stringent specification: there are many ingenious points of arrangement and construction.

RECENTLY I have had the chance to examine, and I now have permission to describe, a set which has some most interesting features. I believe that some of these features could be imported with advantage into many experimental sets.

The builder is a friend of mine who is actually engaged in the industry, and is constantly faced with the necessity of testing sets, components, and circuits. He built this set specially for this work, to fulfil (so he tells me) the following requirements :—

(1) Good reception of broadcasting ;

(2) Must work on all wave-lengths except the very shortest (100 metres, etc.) with equal efficiency ;

(3) Must be adaptable to new circuits ;

(4) Must work with any good components and have facilities for testing the most varied ones ;

(5) Must be variable in power to match any set to be compared with it ;

(6) In view of (2), must have a minimum of switchgear.

Perhaps the most striking points about the general design as actually carried out are: the complete abolition of terminals throughout the set, in favour of "Clix"; the use of valve type four-pin sockets for both H.F. and L.F. intervalve couplings; and the provision of separate filament, grid bias, and H.T. supplies for each valve.

Practically all changes of connections are dealt with by these plugs. The only switches are for the filaments, in the aerial tuning, and two for use with crystal detectors.

Provision is made for three valves, any or all of which can be worked as H.F. or L.F. or Reflex in the simplest manner. The first can be used as detector also very simply; and by special outside connections so can the others. It is also possible, by outside changes, to use any valve as a separate oscillator, to use the set as a superheterodyne, and so forth. Provision is also made for crystal detection.

What the builder calls his "normal" circuit is a reflex with crystal detector, the number of valves varying according to need.

With these preliminaries I will proceed to the actual set. Fig. 1 is a general view to give some idea of the proportions. Fig. 2 is a composite photo of the top and front,

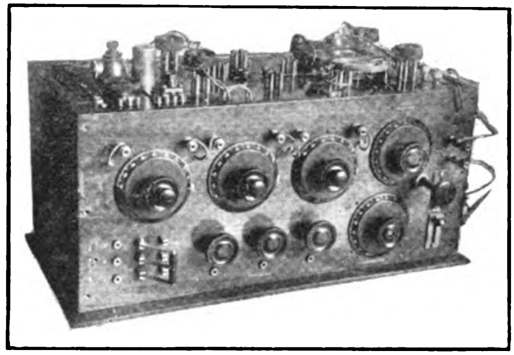


Fig. 1.

A general view, without valves and intervalve couplings.

stripped of components; and Fig. 3 is a schematic diagram. It should be noted that the set itself works from right to left, not left to right as in Fig. 3.

Turning attention first to the aerial circuit (not shown in Fig. 3), this comprises a ·001 condenser with s.p. switch, a Sterling variometer with s.p. switch for the two windings, and a pair of sockets for leads to a loading coil. The condenser and variometer alone give a range from about 200 to 3,000 metres. Each side of the condenser, the loader, and the variometer are accessible for tapping in if required—in fact, such accessibility of "strategic points" is carried out right through the set.

The connection between aerial circuit and the remainder of the set is made by "Clix," so that either part can be used independently, thus leaving the way open for experiment with various types of aerial circuit.

Looking now at the intervalve circuit, the most striking point is the simplicity of the arrangement, in spite of its wide scope. The two coupling sockets are in series, the H.F. being on the valve side: by-pass condensers can be plugged in across the L.F. windings if wanted. Referring to the general diagram, Fig. 3, the H.F. input from the aerial circuit goes via flex leads (two separate leads, not twin flex) to the H.F. input plug. This is shown in Fig. 2. Note that the two left-hand pins are shorted. Hence it can be plugged into any of the H.F. sockets, and the valves before it (to the right in the actual set which works from right to left) are still available for L.F. work if desired.

A similar device is adopted for the H.F. output plug, the flex leads from which go to the detector circuit.

For normal work crystal detectors are used, and the detecting circuit is shown at the upper right-hand corner of Fig. 3. The coil-holder is mounted so that it can be coupled for reaction to either H.F. intervalve transformer: the rectified currents pass to a socket taking an L.F. transformer, and from the secondary go flex leads to the L.F. input plug. As in the H.F. side, anything from one to three L.F. valves can be used, an L.F. output plug taking off the final result and leading it to the output terminals. To provide for the case where the H.F. or L.F. side of any particular valve is out of use, short-circuiting plugs are used.

Three minor points may be noted here: grid leads are brought out to take neutrodyne condensers if required; the crystal detectors may be reversed (often an advantage when used after H.F. valves); and there is a 3-way selector switch for two detectors in the set, with connections for attaching a separate one to be tested.

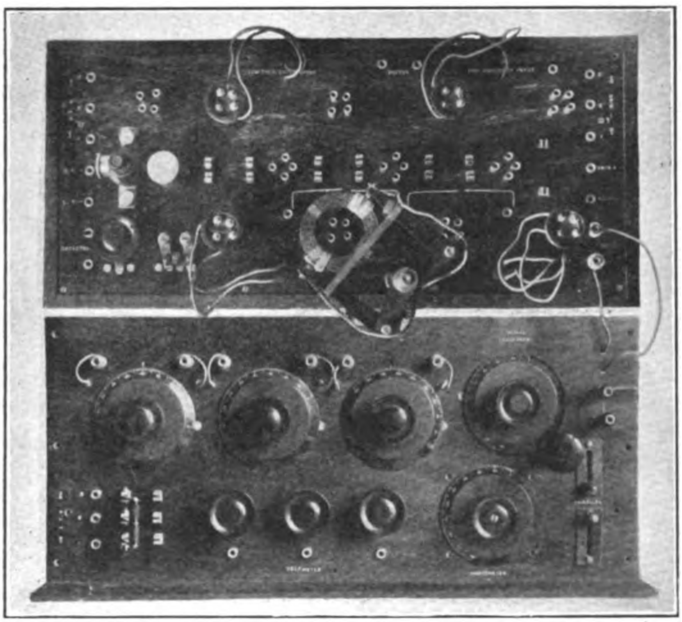


Fig. 2.

The top and front, showing the sockets for valves and couplings, and the use of Clix.

In view of the fact that valves of new types are often being tested, three low tension positives are provided, each of which can, if desired, be connected to 2, 4, or 6 volts. A 3-arm switch breaks all three circuits together: the negative is common. Separate rheostats are provided, microstats being used. I asked the builder of the set whether these were satisfactory, and he was very pleased with them. As to whether they would last he could express no opinion, having had them in use only about six

weeks. A useful point is that a tapping is taken from the filament side of each rheostat to a Clix, for plugging in a voltmeter. The voltmeter negative being permanently connected to the common L.T. —, this enables the filaments to be adjusted accurately to rated voltage—quite an important matter with strange valves.

A somewhat similar refinement exists in the H.F. transformer primary circuits (the primaries are tuned). Instead of taking leads direct from the transformer socket to the condenser, flex leads are brought out through the front of the cabinet to Clix, and the condensers themselves are connected to and the short wave ones home-wound duolaterals of a rather unusual shape which the builder swears by and which certainly seem efficient. They are quite narrow, only ¾ in. instead of the standard 1 in., and carry 5 turns per layer of 28 D.C.C. wire.

To fit the L.F. transformers, those in most common use are mounted on small ebonite bases carrying four valve pins.

The whole set looks rather frightening at first sight—Fig. 4 shows it with transformers and all accessories—but it does not appear difficult to handle on its normal circuit, at any rate by the man who built it, who is by way of being a pretty old hand.

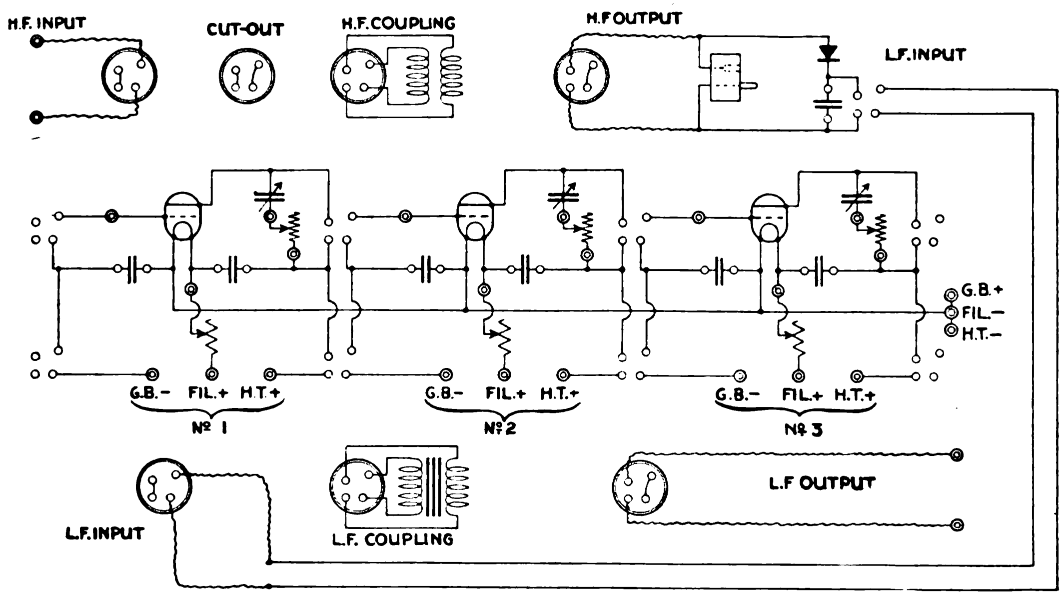


Fig. 3.

Schematic diagram. Double circles signify Clix, small open circles plug-in connections. Above and below are the different types of 4-pin plugs.

Clix set in the front, so that the condensers can be used in other circuits if desired.

About the H.T. and grid battery circuits there is not much to remark, except that a 15-volt unit, tapped every cell, is used as grid battery. This adjustment, in steps of 1·4 volt, is found quite fine enough, I am told.

A separate coil-holder is arranged to give variable coupling with the aerial loading coil: this is used for a separate heterodyne when required for long waves, or for superheterodyne working. It should be noted that the coils used are all gimbal mounted, those for long waves being Igranic "slabs,"

For distant broadcast stations he has usually, when I have been there, worked on three valves, 2 reflex (*i.e.*, 2 H.F., crystal, 3 L.F.) with which he has no difficulty in getting all B.B.C. stations at what I consider excessive loud-speaker strength and excellent tone. Above 400 metres, he gets them through London easily, but below this, *i.e.*, Newcastle down to Cardiff, he has been using a simple series rejector tuned on London. He told me that with three stages H.F. (giving four tuned circuits), he could just dodge London and get Bournemouth, but not Manchester, so he then installed the trap, after which the only difficult one was Cardiff.

This made the circuit much more prone to oscillate. Without it, the set was (whenever I have been with him) beautifully controllable

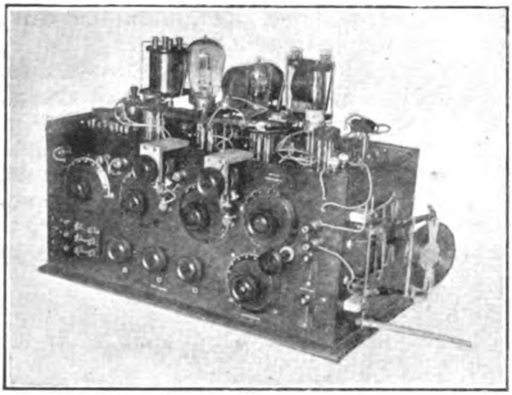
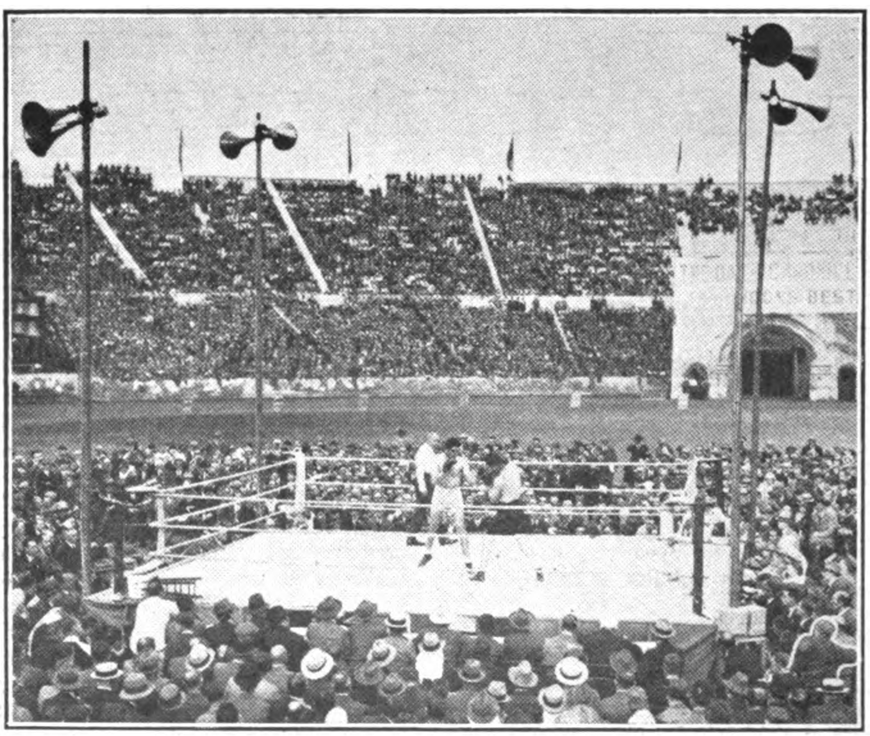


Fig. 4.
A general view complete with accessories.

with 2 H.F., but needed negative reaction with 3. He said that with the rejector he needed negative reaction with 2. This led to a new fitting, shown in Fig. 4, of which the wiring is shown in Fig. 3. This damps down the intervalve transformers: it consists of a 500-ohm potentiometer used simply as a series resistance. My friend considers stabilising by positive grid bias a barbarous method, as the grid adjustment should be governed by considerations of distortion. He does not control the last tuned circuit, as it is already damped by the crystal. He now uses fairly strong positive reaction and then puts in damping resistance till each valve is as near oscillation as he wants, afterwards controlling entirely on the resistances. This control works so admirably in his hands that I am fitting it on my own set. It will be noted that the L.F. amplification (if the valves are working reflex) is quite unaffected.

Altogether, the set is an interesting one, and I am taking several of the ideas into use on my own set. The builder desires to remain anonymous, but has expressed his willingness to give further particulars to anyone interested: I shall be delighted to pass on any inquiries.



The advantage of being a great inventor: Capt. Round at the ring-side at the big fight at Wembley, watching over his microphones and loud-speakers. He is in the right lower corner, outlined in white.

A Simple Method of making Direct Current Measuring Instruments.

By Leonard A. Sayce, M.Sc., A.I.C.

THE high cost of accurate measuring instruments is one of the greatest obstacles that the amateur experimenter has to face. It is because of this that so much work has to be done by "rule of thumb" methods, and the predominance of the personal element in tests that should be quantitative leads to many conflicting reports of various devices. It is thought, therefore, that a short account of the principles upon which these instruments depend and of a simple means of making them may meet the needs of many.

Most sensitive voltmeters and ammeters for direct current measurements are of the Moving-Coil type, that is to say, they contain a rectangular coil of wire free to turn against the restraining action of a spring in a powerful magnetic field. If a current is flowing through the coil, the amount that the coil

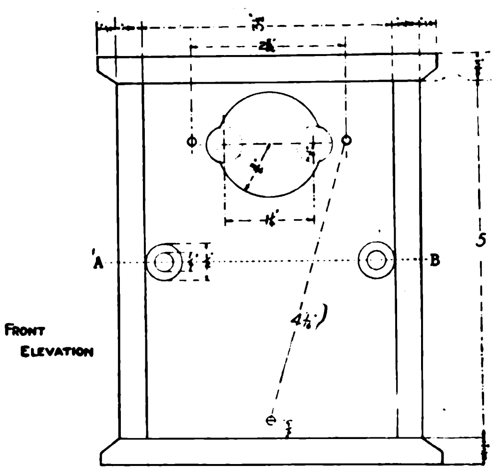


Fig. 1.

is rotated is proportional to the current, if the magnetic field is uniform and the controlling spring uniform in action. To obtain great sensitivity, the coil is pivoted between jewel bearings (like the balance-wheel of a watch) and is wound with many turns of fine wire. If this were all, the instrument would not be aperiodic (or dead-beat), but when in use the pointer, which is attached to the coil,

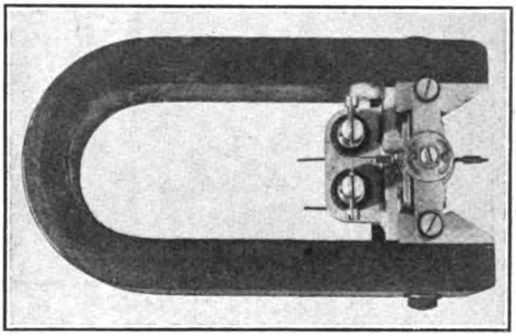


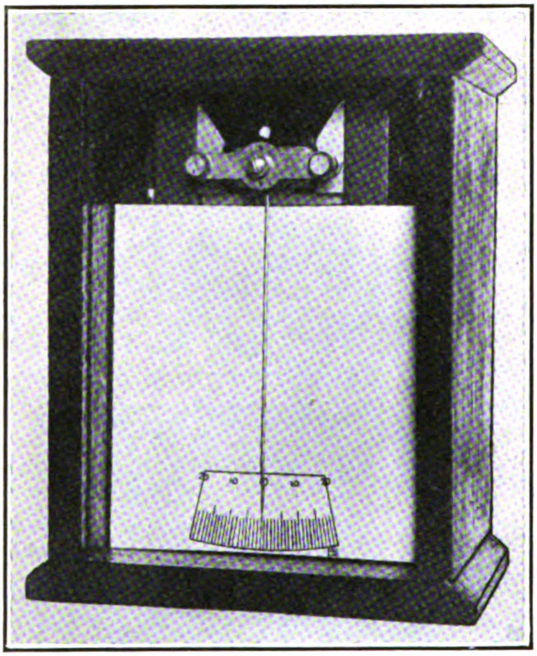
Fig. 2.

would oscillate backwards and forwards for some time before coming to rest at the right place. The delay and unnecessary wear that would be caused in this way are prevented by winding the rectangular coil upon a metal frame or former. When the coil moves, eddy currents are induced in this frame and these eddy currents produce a magnetic field which, reacting with that of the permanent magnet, opposes the motion of the coil. This form of damping can be made so effective that the coil moves to its final position without any delay or over-shooting the mark.

The "Weston Moving-Coil Relay" is an instrument of this type, and it can readily be converted into either a sensitive galvanometer for indicating currents or into a meter for measuring them. It can now be obtained for about half-a-guinea from vendors of ex-Government stores. The moving coil is wound to a resistance of approximately 350Ω* and current is conveyed in and out of

* The coils for three relays were found to have a resistance of 337Ω, 343Ω and 360Ω respectively.

the coil by two fine hair-springs. The coil turns in agate bearings between the curved

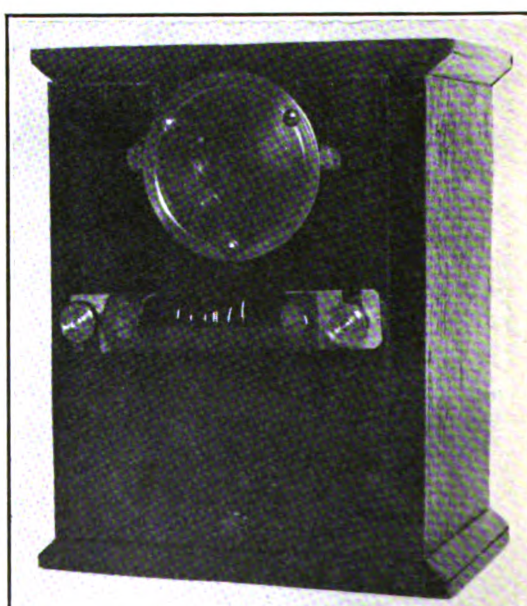


pole-pieces of a powerful permanent magnet and consists of a rectangular aluminium frame wound with many turns of fine wire. The local current is led through a third hair-spring to a brass wire carrying a platinum strip which, when the coil moves, completes a local circuit by touching one or other of two platinum-tipped screws. A current of ·000015 amp. is sufficient to work the relay.

Very few modifications are required to make the relay into a satisfactory galvanometer for bridge work or into an ammeter or voltmeter of any required range. A mahogany box is required, whose dimensions are shown in Fig. 1. The back of the box should be of $\frac{3}{4}$ in. wood, having a tongue at each side to enable it to slide in groves in the sides of the box. It should also be provided with a hole of the size and shape shown and be fitted with two terminals in ebonite-bushed holes.

The relay is modified as shown in Fig. 2. The marking and spacing contact-screws are removed entirely. The platinum contact-strip, attached to the moving coil, is removed by touching it with a miniature soldering-iron made from thick copper wire, as also is the hair-spring by which the current is led to the moving contact. The removal of this spring renders the instrument much more sensitive. Upon the stump of brass wire, from which the contact was taken, a light pointer is now attached. This pointer should be $3\frac{5}{8}$ in. long and must be very light but rigid. Such a pointer may be made by cutting a strip of thin aluminium foil $\frac{5}{64}$ in. wide and about 4 in. long. One end is cut to a point and threaded through a wire draw-plate. By drawing the strip through successively smaller and smaller holes the edges are bent round to form a tube that is rigid but extremely light. (The weight of such a pointer of the dimensions given need not exceed 0·02 gm.) One end is flattened out into a fine blade, cut off obliquely and dipped into indian ink. When the ink has dried, the tube is cut to a length $3\frac{5}{8}$ in. The un-flattened end is slipped over the stump of brass wire and fixed in place with a little shellac. The tip of the pointer will then move in an arc of a circle of 4 in. radius.

It is now necessary to balance the weight of the pointer. Three little balance-weights will be found near to where the pointer is attached. The balance-weight lying diametrically opposite to the pointer is screwed



out until it is balanced, and it will usually be found necessary to increase the mass of

the balance-weight by a small globule of solder. The relay may now be fitted to the back of its box. This is done by means of the three attachment screws that are provided with the relay. The heads of these screws require to be deeply countersunk. The large hole in the back of the box takes the back bearing of the coil and gives access to the two hair-springs for zero adjustment. Two rubber-covered leads are connected to the terminals and to the hair-spring supports respectively and, after the zero adjustment has been made, the hole in the back of the box is closed by a brass disc 2 in. in diameter.

The scale may be drawn on Bristol board with a very fine drawing-pen, but the writer has found it easier to draw the scale three times its proper size and then reduce it photographically. The divisions of the scale must be fine, for the Weston relay has one disadvantage as a measuring instrument: the movement of the coil is limited to about 25° and this corresponds to 40 mm. at the end of the 4 in. pointer. For a nul instrument this is no disadvantage, but for a measuring instrument we must get over the difficulty to some extent by using a very fine pointer (made as described above) and a finely divided scale. The available 4 cms. should, therefore, be divided into millimetres and, seeing that with practice it is easy to read correctly to one-tenth of a division, the scale may then be read to one part in four hundred. If the relay is for use merely as a nul galvanometer the scale is marked with a central zero, but if it is required as a measuring instrument the zero should be at the left-hand end of the scale. If the instrument is now tested the pointer will be found to move one scale division when a current of from 4 μA to 8 μA (0·000 008 amp.) is passed through the coil.* It can therefore be used as a microammeter* if the scale is first calibrated by reference to a standard instrument. In the absence of such a standard the converted relay may be connected in series with a reliable 1Ω grid leak and a variable high tension battery. For every volt used from the battery a current of 1 μA will traverse the circuit.

* The exact sensitivity depends upon the adjustment of the hair-springs and the care taken in balancing the pointer.

Nodal Points and Aerial Tuning.

By P. K. Turner.

In response to a request from an amateur transmitter, the question of the nodal points and natural frequencies of a loaded aerial working on its harmonics is dealt with by simple calculation.

NOT long ago I was discussing, with a serious and very successful amateur transmitter, the question of Nodal Points in the Aerial, when working on short waves. On my stating that the approximate position of the voltage nodes could be derived from "the old ql equation," I found that he had somehow not come across the fundamental equation of aerial tuning.

In case there are others doing work on the same problems, I give a few notes on the matter.

The problems are: What is the required loading (coil and condenser) to tune an aerial of known capacity and inductance to a given wave-length; and what is the current or voltage distribution over the aerial. The latter problem obviously gives the nodes, which are defined as points where the voltage is zero.

To simplify matters, I shall neglect the aerial resistance, which would complicate the calculations enormously. Although it greatly affects the *amplitude* of the current, it does not greatly affect the tuning or the distribution. Secondly, I shall assume that the aerial has a constant capacity and inductance per foot run over the whole of its length. This is more nearly true for short amateur aerials than for big "roof" commercial, long-wave aerials. The result of an uneven distribution would be a shifting of any nodes that exist up in the aerial itself. The point will be taken up later. Lastly, only the case of an earthed aerial is dealt with in detail. At the end of the article I show how to apply the results to a counterpoise.

It is not proposed to give the derivation, by calculus, of the main current and voltage equations: the reader must take my word for it that they are correct. They are as follows*:—

* See any standard work such as Fleming, Morecroft, etc.

Let e_x be the voltage x feet from the bottom.
i_x the current x feet from the bottom.
L_0 the aerial inductance (Henries).
C_0 the aerial capacity (Farads).
l the aerial length (in feet if x is in feet).

then $e_x = A \cos \overline{ql - qx} \cos \omega t$ .. .. (1)

$$i_x = A\sqrt{\frac{C_0}{L_0}} \sin \overline{ql - qx} \sin \omega t \quad .. \quad (2)$$

where ω is the impressed frequency $\times 2\pi$
A a constant depending on the amplitude of the impressed voltage (see below)
and q is given by the equation

$$ql = \omega\sqrt{L_0 C_0} \quad .. \quad .. \quad (3)$$

Pausing just for a moment to consider the physical meaning of these equations, we see that both voltage and current are of the usual alternating sine-wave form as regards tune. But the amplitude—the value when $\cos \omega t$ or $\sin \omega t$ is 1—itself depends on the distance up the aerial.

Confining ourselves to the amplitudes, we have

$$E_x = A \cos q(l - x)$$

$$I_x = j A\sqrt{\frac{C_0}{L_0}} \sin q(l - x)$$

where $j = \sqrt{-1}$ and signifies that the current is 90° out of phase with the voltage.

Now the voltage impressed on the aerial is that at the foot. If we call it E, we have

$$E = E_0 = A \cos ql$$

$$A = \frac{E}{\cos ql}$$

So that $$E_x = \frac{E}{\cos ql} \cos q(l - x) \quad .. \quad (4)$$

$$I_x = j\frac{E}{\cos ql}\sqrt{\frac{C_0}{L_0}} \sin q(l - x) \quad (5)$$

From these we can find the values at the foot and the extreme end :—

$$E_e = \frac{E}{\cos ql} \cos 0 = \frac{E}{\cos ql} \quad .. \quad (6)$$

$$I_e = j\frac{E}{\cos ql}\sqrt{\frac{C_0}{L_0}} \sin 0 = 0 \quad .. \quad (7)$$

$$E_0 = \frac{E}{\cos ql} \cos ql = E \quad .. \quad .. \quad (8)$$

$$I_0 = j\frac{E}{\cos ql}\sqrt{\frac{C_0}{L_0}} \sin ql$$

$$= jE\sqrt{\frac{C_0}{L_0}} \tan ql \quad .. \quad .. \quad (9)$$

The impedance of the aerial to the impressed voltage (which, as we are neglecting resistance, is equal to its reactance) is obviously the ratio of voltage to current at the foot. Calling it X_0, we have from (8) and (9)

$$X_0 = -j\sqrt{\frac{L_0}{C_0}} \cot ql \quad .. \quad (10)$$

The Voltage Nodes.

Now it is obvious that the "Nodal Points" (a better term is "Voltage Nodes") are the points where $E_x = 0$. Looking at equation (4), we see that the condition for this is

$$\cos q(l - x) = 0 \quad .. \quad .. \quad (11)$$

As we all know, the cosine of an angle is zero when the angle is 90° ± (180° × any whole number), or, using the usual radian measure,

$$q(l - x) = (2n + 1)\frac{\pi}{2} \quad .. \quad (12)$$

where n is any whole number.

We will express this in terms of wave-length. If q_0, λ_0, f_0, ω_0, refer to the fundamental frequency or wave-length of the unloaded aerial, then λ_0 is given by the condition that the reactance of the aerial at this frequency is zero, or (from equation (10))

$$\cot q_0 l = 0$$

or $$q_0 l = (2n + 1)\frac{\pi}{2},$$

or, for the fundamental,

$$q_0 l = \frac{\pi}{2}, \quad n \text{ being } 0 \qquad .. (13)$$

Thus we have, for the nodes (from (12))

$$ql - qx = (2n+1)\frac{\pi}{2} = (2n+1)q_0 l$$

or, dividing by ql,

$$1 - \frac{x}{l} = (2n+1)\frac{q_0}{q} = (2n+1)\frac{\lambda}{\lambda_0},$$

since q varies as ω (see (3)), hence varies as f, and therefore varies inversely as λ.

Rearranging, we have

$$\frac{x}{l} = 1 - (2n+1)\frac{\lambda}{\lambda_0} \qquad .. \qquad .. (14)$$

This gives at once the positions of all the nodes in the aerial itself. Take, as an example, an aerial 100 ft. long in all, of 200 metres natural wave, being worked on 45 metres.

$$\frac{x}{l} = 1 - (2n+1)\frac{45}{200}$$

Now the possible values of n are limited by the facts that $\frac{x}{l}$ must be positive and less than 1. (We are not investigating nodes in the ground or beyond the end of the aerial !)

We have the following table of results :—

n	-1	0	1	2
$2n+1$	-1	1	3	5
$(2n+1)\frac{45}{200}$	$-\cdot225$	$+\cdot225$	$+\cdot675$	$+1\cdot125$
$\frac{x}{l}$	$1\cdot225$	$\cdot775$	$\cdot325$	$-\cdot125$
x	——	77′ 6″	32′ 6″	——

There are, therefore, two nodes, at 32 ft. 6 in. and 77 ft. 6 in. from the foot of the aerial. As mentioned above, deviations from our original assumption as to even distribution of capacity and inductance will shift the positions somewhat. If there is a single lead-in and multiple top, for example, the nodes will be shifted upwards. But their number will not be changed : further, their position is independent of loading and tuning (provided the frequency is kept constant by forced oscillations) : *the nodes depend only on the ratio of the frequency in use to the fundamental of the unloaded aerial.*

Loading and Wave-length.

Next, as to the loading required for a given wave-length. As we are dealing with short waves, we will consider only a load of capacity and inductance in series : the parallel case can be taken up in a later article if desired.

Suppose we insert an inductance L_s henries, and a capacity C_s farads, the inductance having negligible self-capacity and the condenser and its leads negligible self-inductance. Then we have placed between aerial and earth a reactance X_s, given by

$$X_s = j\left(\omega L_s - \frac{1}{\omega C_s}\right) \qquad .. \qquad .. (15)$$

If now the aerial and load are tuned as a whole to the frequency of $f\left(=\frac{\omega}{2\pi}\right)$, then the total reactance is nil, *i.e.*, $X_s + X_0 = 0$, or $X_s = -X_0$, whence, from (10) and (15)

$$\omega L_s - \frac{1}{\omega C_s} = \sqrt{\frac{L_0}{C_0}} \cot ql \qquad .. (16)$$

Remembering that $ql = \omega\sqrt{L_0 C_0}$, and that by supposition L_s, C_s, L_0, and C_0 are known, it is obvious that this equation will give us ω, and hence the wave-length. But it cannot be solved directly. However, a graphical solution is easy, and we will carry it out.

To simplify matters, we will take a concrete case ; that of an aerial of $\cdot 0004\ \mu F$, with 64 μH of inductance. First we will plot a curve of cot ql for various frequencies. As an example, if f is 159 000 cycles, ω is 1 000 000, or 10^6. Now $ql = \sqrt{L_0 C_0}$, and is easily found to be $\frac{\cdot 155\omega}{10^6}$: for this case it equals ·155. Now to find *cot ql* from ordinary tables, we must convert to degrees by multiplying by $\frac{180}{\pi}$, which gives us 89°. From any table of cotangents, cot $ql = 5\cdot67$, and as $\sqrt{\frac{L_0}{C_0}} = 400$, we have $(-X_0) = 2270$ ohms approx.

Calculating for other frequencies in the same manner, we arrive at the heavy lines marked X_0. in Fig. 1. The points where

these lines cross the horizontal axis are the frequencies of zero reactance, *i.e.*, the natural wave-lengths of the aerial alone. Expressing them in terms of the fundamental (point A) as a unit, their frequencies are 1, 3, 5, 7, 9 . . . etc. These lines are always the same for the same aerial, whatever the loading.

Now imagine the aerial loaded by an inductance of 50 μH. The reactance of this is given by $X=50\omega$, and is easily drawn as the straight line B. Now at the points where line B cuts lines X_0, we have $X_s=-X_0$, or the aerial and coil are tuned. Therefore the natural frequencies of the loaded aerial are the points marked by circles on line B. It is interesting to note their frequencies in terms of the fundamental A. We observe

$$\frac{f}{f_0} = \cdot 85,\ 2\cdot 4,\ 4\cdot 3,\ 6\cdot 27,\ 8\cdot 25,$$

corresponding to harmonics of the free aerial at 1 3 5 7 9

As would be expected, the loading coil lowers the natural frequency in every case (*i.e.*, increases the wave length). But, expressing the harmonics of the loaded aerial in terms of *its own* fundamental, we have

1 2·8 5 7·4 9·97

The harmonics are not even multiples of the fundamental.

If we remove L_s and substitute C_s, of ·0001 μF, its reactance $\left(=\frac{1}{\omega C_s}\right)$ is given by curve C. The natural frequencies, in terms of the free fundamental A, are

1·8 3·65 5·55 7·5 9·5

showing increased frequency. In terms of the loaded fundamental,

1 2·03 3·08 4·16 5·27,

a very great divergence from the 1, 3, 5, 7, 9 of the free aerial.

Lastly, suppose both the condenser and the inductance to be inserted. The curve of X_s will then be the (algebraic) sum of curves B and C. It is shown as curve D, and the natural frequencies are shown by the points marked by triangles. We now strike a particularly interesting feature. The frequencies, in terms of A, are

1·7 2·9 4·4 6·3 8·25

or in terms of the loaded fundamental,

1 1·7 2·6 3·7 4·8

an even greater divergence than before from the harmonic series for the free aerial.

The fundamental frequency is increased in the ratio 1·7 by this loading; *i.e.*, the wavelength is decreased in this ratio. But the next harmonic is hardly altered, while all the higher ones are *decreased* in frequency!

By the simple method of drawing other X_s lines on the same diagram, any combination of loading may be investigated. We have drawn (dotted) lines for 20 μH inductance (marked E) and ·0002 μF capacity (marked F).

Hours might well be spent on studying such curves. We will just note three important points:—

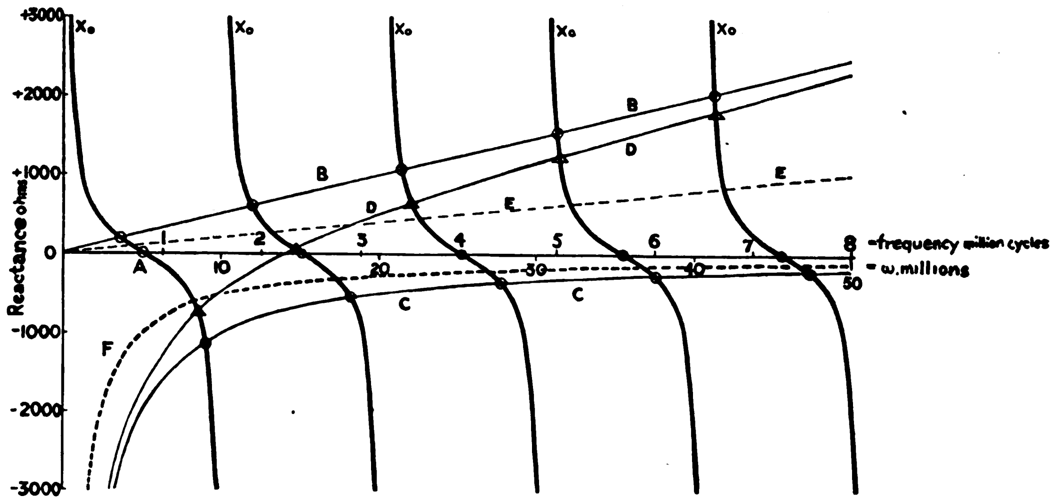


Fig. 1.

(1) No loading of any kind can make one harmonic "trespass" on the space of another. For example, the fourth X_0 curve covers frequencies giving between 31 and 41 million for ω. No loading can increase this harmonic to 42 or reduce it to 30.

(2) The effect of inductive loading is greatest in the harmonics.

(3) The effect of capacity loading is greatest on the fundamental.

Nodes in the load.

A question asked in the original conversation which led to this article was: "Can one have a node in the loading coil or condenser?"

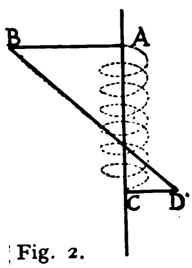


Fig. 2.

This can be decided as follows:—

If we have a loading coil L_s above a condenser, and the voltage set up in it is E_L, then

$$E_L = j\omega L_s I_0 = -\omega L_s\sqrt{\frac{C_0}{L_0}}\tan ql.\ E_0 \text{ from (9).}$$

Now the voltage at the foot of the inductance is

$$E_0 - E_L = E_0\left(1 + \omega L_s\sqrt{\frac{C_0}{L_0}}\tan ql\right) \quad .. \quad (17)$$

If this difference is negative (*i.e.*, $E_l > E_0$) there will be a change of sign between the voltage above and below the inductance, so that there must be a node at some point on it. This will be the case if *tan ql* is *negative*, and of value greater than

$$\frac{1}{\omega L_s}\sqrt{\frac{L_0}{C_0}}$$

Since tan ql varies from $-\infty$ to $+\infty$ in quite a small range of ω, this is obviously possible at certain frequencies. Further, if it is found that at a certain frequency there is a node, its position on the coil is easily found. Suppose that in Fig. 2 the voltage at foot is found to be $\frac{1}{3}$ of E_0, we can draw lines AB, CD, making $\frac{AB}{CD}$ in the ratio $\frac{E(\text{foot})}{E_0}$ ($=\frac{1}{3}$ in this case).

The line BD cuts the centre of the coil at the node. This, of course, is only an approximation, for it assumes that every turn has equal inductance. Without this assumption, we can say (calling L_N the inductance of that part of the coil *above* the node,

$$\frac{L_N}{L_s} = \frac{E_0}{E_L}$$

from which L_N, and hence the proportion of turns, can be found.

In the case of the condenser being above the inductance, it can be proved in the same way that there will be a node if *tan ql* is *positive*, and of value greater than

$$\omega C_s\sqrt{\frac{L_0}{C_0}}$$

There can obviously never be a node in a pure inductance or condenser next to the earth connection, as its bottom end is itself a node.

The Counterpoise.

Hitherto, we have worked on the basis of an earthed aerial, but the results can be extended in a simple manner (see Fig. 3). Here we have a circuit consisting of aerial A, tuning condenser C_s, coil L, counterpoise condenser C_c and counterpoise C. The circuit is earthed at E. Now if we consider the coil to be split at E, forming an aerial coil L_a and a counterpoise coil L_c, we have obviously two circuits, AC_sL_aE and CC_cL_cE, each of which can be dealt with as indicated.

One important point is instantly shown by this. We have already proved that for a given impressed voltage the current is proportional to $\frac{C_0}{L_0}$, or, in another form, to pass a given current we must impress a voltage proportional to $\frac{L_0}{C_0}$. Now this fraction will probably be different for the aerial and the counterpoise. So if, as is usual, we want the earth lead to be simply a stabiliser carrying no current, we must adjust the impressed voltage on the counterpoise accordingly, so that the currents in A and C are equal. This will probably be done by varying L_c— of course C_c must be varied in turn to bring the counterpoise back to the right tune.

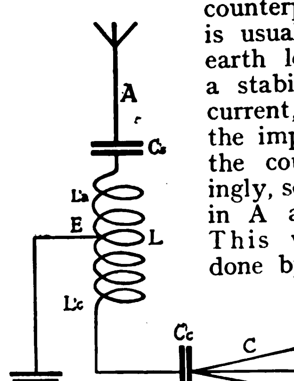


Fig. 3.

A Full Wave Rectifier.

By Herbert H. Dyer, A.M.I.E.E.

In the following article the author describes how he constructed a full-wave rectifier from an ex-W.D. D III. buzzer, and also details the operation of this novel piece of apparatus.

A NUMBER of experiments have been carried out by the writer, when time could be spared from purely "wireless" work, with the object of designing a really satisfactory rectifier for charging filament batteries from alternating current mains. A tuned reed rectifier had been used previously, but although this, on the whole, gave satisfactory results, it was found that slight variations in frequency or sudden changes in the voltage of the supply caused some sparking at the contacts. As it was desired occasionally to leave the charging in unskilled hands, it was decided to design a rectifier that would not be affected by these changes in the supply. The aim was to obtain something that would run absolutely sparklessly without adjustment for many months, using both halves of the wave. After a gratifying amount of success with various arrangements, the writer was fortunate enough, in one of his periodical searches amongst ex-W.D. apparatus, to discover what appeared to be the very thing for the purpose. This was a buzzer from a D III field telegraph set, and it actually exceeded expectations. It is safe to say that a better rectifier could hardly be designed for the purpose, and no alteration at all was required except in the connections.

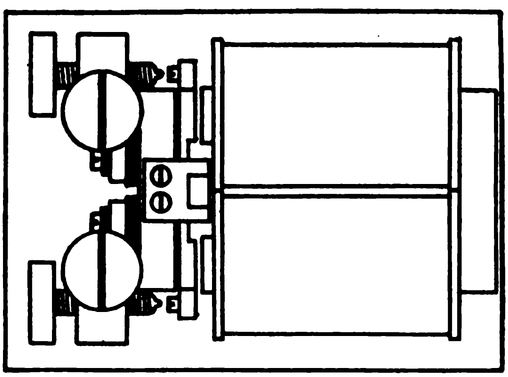


Fig. 1.
The D III Polarised Buzzer.

It is proposed to describe the arrangement and to give the results of tests carried out with it.

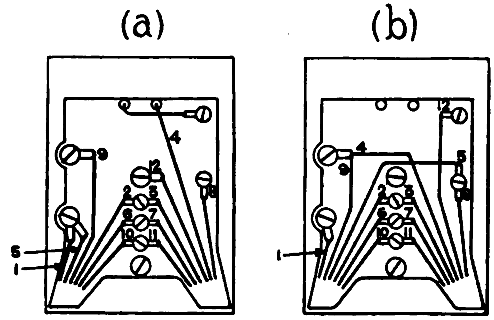


Fig. 2.
Back connection of D III Buzzer.

For the benefit of those unfamiliar with the D III buzzer, the following short description is given. A pair of coils with iron cores are fixed on a U-shaped magnet, forming an almost closed magnetic circuit. In the gap and across the ends of the two cores is the armature, which is fixed at the centre to a flat spring. Screwed on each side of the armature is a short contact spring. The contact screws are fastened to the magnet and, of course, insulated from it. Fig. 1 shows the buzzer in plan.

Each coil consists of three separate windings, the resistances being approximately 1·6 ohms, 1·6 ohms and 32 ohms respectively. The vibrator is fixed on an ebonite base $3\frac{3}{8}$ in. × $2\frac{1}{4}$ in. × $3\frac{1}{2}$ in. thick, the overall height of the vibrator being $1\frac{5}{8}$ in.

On the first buzzer the writer obtained the magnet was demagnetised, in fact it was quite soft and could be readily filed. Consequently the 32 ohm windings were used for polarising the armature, the windings being connected in such a way as to produce similar poles at the open ends of the two cores. The other four windings (two on each core) were joined in series and connected to the A.C. supply. The connections must be such that a current in either

direction produces opposite poles at the open ends of the two cores.

Fig. 2 (*a*) shows, from the back, the original connections of the buzzer, and 2 (b) shows the connections altered for use as a rectifier. The operating windings are from 1 to 12, *i.e.*, four coils, each about 1·6 ohms, connected in series. The magnetising windings are from 6 and 7 to 5 and 8, *i.e.*, two coils, each about 32 ohms connected in parallel. The operation will now be obvious, the flux due to the alternating current acting on the polarised armature causes it to vibrate at exactly the same rate as the frequency of the supply. As the armature is not tuned, the operation of the buzzer is equally satisfactory at all ordinary supply frequencies.

A transformer is necessary, not only to step down the voltage to the required value, but to provide a centre point for full-wave rectification. The secondary winding of the transformer has a tapping at the centre. The outside ends of the secondary are connected to the contact screws of the buzzer, and the centre tapping of the secondary is connected through the battery to the armature of the buzzer. The transformer used was of the "Hedgehog" type, the core being of soft iron wire. The diameter of the core

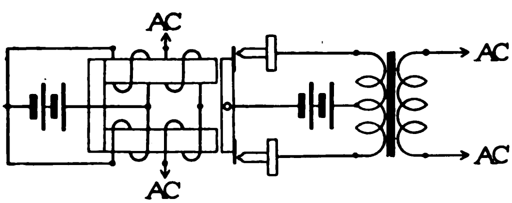


Fig. 3.
Connection of Buzzer for use as Rectifier.

was about two inches, and about five and a half pounds of iron wire was used. The primary consisted of 2000 turns of No. 30 D.C.C. wire, each layer being carefully wound on the lathe and well shellacked, with, shellacked paper between the layers. The secondary was wound with 140 turns of No. 18 D.C.C. wire in two layers, with a tapping at the centre and tappings at 60 and 65 turns each side of the centre. The shellac was dried out by passing a direct current through the primary for about twenty-four hours. The supply is rated at 200 volts but is rather higher and varies considerably. The secondary voltage was arranged for charging four-volt batteries only at from three to five ampères.

OPERATION.

Having briefly described the construction and connections of the rectifier, the operation can be discussed. Referring to Fig. 4, the sine wave represents the secondary terminal

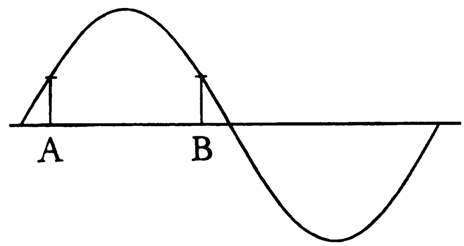


Fig. 4.
Showing conditions for sparkless rectification.

voltage. In order to get sparkless rectification the "make" and "break" must occur exactly at the points A and B, where the secondary voltage just balances the battery voltage. Unless the movement of the armature is precisely in step with the secondary voltage, sparkless rectification is impossible. If the operating coil of the vibrator is connected directly across the secondary, the movement of the armature will lag considerably behind the secondary voltage, owing to the highly inductive nature of the winding. The operating coil was consequently connected to the mains through resistances and condensers in order to ascertain the best arrangement. It was eventually found that a 4 μF condenser connected in series gave absolutely sparkless rectification. The contact screws are provided with a very fine thread, and adjustment is thereby considerably simplified. The best method of adjusting for full-wave rectification is to draw one of the contact screws right back and adjust with the other for half-wave; then gradually bring up the first contact screw until the sparkless point is reached. It will be found that this does not upset the original half-wave adjustment, and the ammeter should give the same reading with either side disconnected. The writer's rectifier has been running for about a year without giving any trouble, and no spark at all is visible, even in the dark, at full load. In the arrangement actually used the magnetising current is provided by the battery on charge.

TABLE I.

Secondary Voltage		Battery Voltage V_3	Charging Current		Input from Mains			Output Watts V_3A_2	Efficiency
Open Circuit V_2+V_2	Closed Circuit V_2+V_2		P.N. Inst. A_2	H.W. Inst. A_3	Volt-Amps V_1A_1	Watts W	Power Factor		Per cent.
—	—	—	No Load		53	8	·15	—	—
			Amps.	Amps.					
6·5+6·5	5·6+5·6	4·5	3·1	5·5	66	40	·61	14	35
7·3+7·3	6·1+6·1	4·5	4·5	7·0	73	54	·74	20	37
7·8+7·8	6·4+6·4	4·6	5·0	7·5	80	61	·76	23	38

A number of tests were made to ascertain the efficiency. Fig. 5 shows the connections for the test, where it will be noticed that a separate battery was used for magnetising. V_1 is an A.C. voltmeter, W a wattmeter, A_1 an A.C. ammeter, V_2 A.C. voltmeters, A_2 a D.C. ammeter, A_3 a hot-wire ammeter, and V_3 a D.C. voltmeter. A selection of the figures is given in the table. The vibrator itself took about 8 watts, the power factor being only ·15. The difference between the readings on the D.C. ammeter and the hot-wire instrument is interesting. current indicated on the D.C. instrument was the same as that indicated on the instrument in the D.C. charging circuit the two batteries came up together. This test was repeated several times at different charging rates, with exactly the same result.

The small current used for magnetising the buzzer has not been taken into account when reckoning the efficiency. The writer believes that the rectifier would operate equally well when using a permanent magnet, but has not, up to the time of writing, been able to

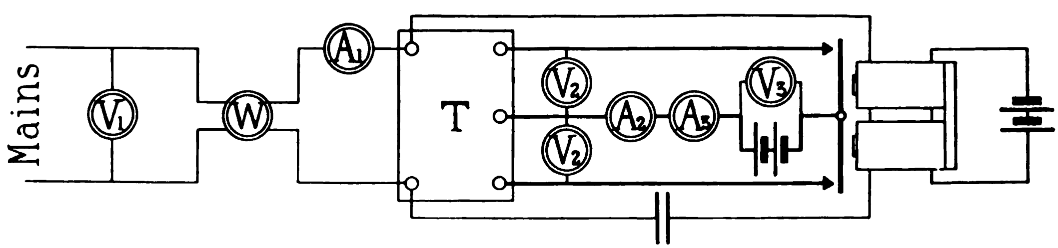


Fig. 5.
Connections for Efficiency Test.

To prove that the reading given by the moving coil instrument indicated the effective current for charging the battery, a batch of new cells was charged several times from the D.C. supply and a discharge test made after each charge. Readings were taken every hour, both during charge and discharge. Four of the cells which gave identical results hour by hour were then selected, and two of them charged from the D.C. mains and two from the rectifier simultaneously. It was found that when the rectified charging give this an extended trial. The advantage of magnetising from the cell on charge is that it does not matter which way the battery is connected to the charging terminals. With power at one penny per unit it will be seen that eighty ampère-hours can be put into the battery at a cost of one penny.

The rectifier can be used satisfactorily without the transformer for charging secondary H.T. batteries, the current being regulated by means of a lamp resistance.

5XX.

A technical description of the first British high-power station designed throughout for distortionless telephony.

IN attempting to describe such a station as 5XX, one is confronted with various difficulties. First, where does the "station" begin? Inasmuch as the microphone and the A and B amplifiers are of the usual B.B.C. type, we have decided (somewhat arbitrarily we fear) to keep to the transmitter itself, beginning with the leads coming into the transmitting house from the sub-control.

These carry a power (pure A.C. power) in the neighbourhood of 10 to 30 watts. They go to the primary of the control input transformer, which is of 10 : 1 ratio, the primary having 2040 turns.

Another difficulty is that, although casual inspection of the set has been fairly freely allowed, one finds when detailed and expert inquiry is made that various details are highly confidential.

By courtesy of the B.B.C. and the Marconi Co., we were able to make a detailed investigation, and our notes and results have very kindly been checked by Capt. Round; but it will be understood that certain details are of necessity omitted.

Dealing now with the apparatus in the main transmitting house, the set may be, for purposes of description, divided into three clear-cut parts, though in the actual experimental station in use it is not so clearly divided. There is, first, the drive oscillator, next the magnifier or main power amplifier and aerial circuit, and third the modulator.

The Drive Oscillator.

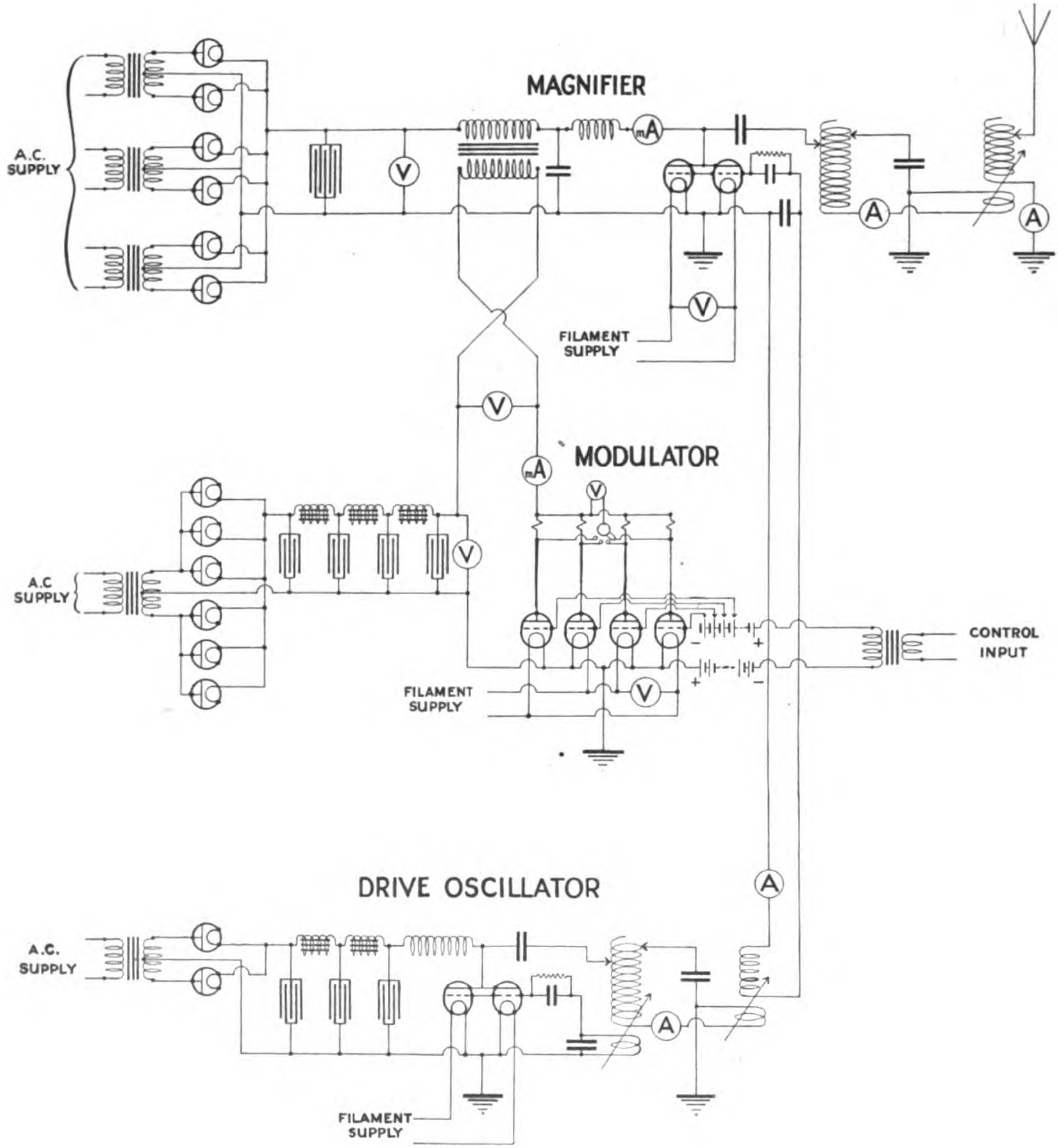
The circuit of this, as will be seen from our diagram, is simplicity itself—as, in fact, are all the circuits. It is an ordinary back-coupled oscillator with branched H.T. circuits, employing two M.T. 7a valves. These are of the ordinary "Bottle" type, one of them being illustrated. They are rated to dissipate about 1 kW if necessary. Their main characteristics are $\mu=72$, $R_a=30\,000$; the filaments each take about 25A at 12V. The filaments are supplied by the same D.C. generator that feeds the magnifier and modulator valves (see below).

The grid circuit comprises first a condenser-leak combination, the leak having a value of 15 000 O, and the condenser ·0046 μF. The D.C. grid current is given as 80mA, from which we see that the leak will depress the mean grid potential to −1200V. This large value is not surprising in view of the large H.T. supply, as will be noticed presently. The anode circuit being tuned, the grid circuit would be normally aperiodic, but it is found that the coupling may be weakened and a smaller coil used by partially tuning the grid circuit. The grid coil of 700 μH. is therefore shunted by a condenser of ·0005 μF, giving a natural wave-length 0·7 of that of the anode circuit.

Of the two branches of the anode circuit we shall deal first with the H.T. supply. This is derived primarily from a 6 kW alternator, giving single-phase current at 500V, 300∼. This is transformed up to 10 000V, and applied to a full-wave rectifier consisting of two M.R.7a. valves, these being two-electrode valves of power corresponding to the M.T.7a's used as oscillators. Their filaments are fed *via* a transformer from the same supply as those of the other rectifiers, as described below.

The rectified output is smoothed by two 45H chokes and three condensers (of ·25, ·125, and ·125 μF.). It is then applied to the anodes *via* a radio choke of 4200 μH, consisting of three single-layer coils wound on porcelain. This obviously offers a reactance of 5000O to currents of 1600 meters wave-length. The current amounts to 180mA on the two valves, or a total input of 1·8 kW.

The output anode circuit commences with a stopping condenser of ·000 6μF. of the Moscicki tube type, offering a complete stop to D.C. currents and a reactance of 10000O to the high frequency.



THE CIRCUITS OF 5XX.

In this drawing, in order to keep that simplicity which makes for ease in reading, the power supply circuits, which are of quite a normal type, are cut out, as are also the filament circuits for the rectifiers. Certain small omissions have been made, as there are one or two confidential points of design. The constants of the various items have not been inserted, as their inclusion is somewhat confusing. They are given in the accompanying description.

Next to this comes the main coil of heavy litz wire on a skeleton former. It is of 300 μH, with separate tappings for the anode and for the output circuit. In series at the lower end of it is the coil coupling to the input of the magnifier, and across the two is the tuning condenser, of ·002 μF. This is an open condenser with air dielectric and is fixed, adjustments being made by the taps on the coil and by a small variometer (not shown in the diagram). The H.F. current in this circuit is normally 25A. The lower end of the condenser is earthed, thus providing the filament connection for the anode circuit.

The Magnifier.

The coil coupled to the circuit last described forms part of the grid circuit of the magnifier, which we will now consider in detail.

It consists of a bank of two water-cooled valves in parallel. These valves, made by the M-O Valve Co., have not yet received their final nominal rating. It is believed, however, that they will stand up to an anode dissipation of 20kW each. At present they are being used at lower power, on a basis of 10kW. Their main characteristics are $\mu = 30$, $R_a = 10\,000\Omega$: the filaments take 40A at 20V each. In common with the modulator and drive oscillator filaments they are supplied in this set by a 10kW D.C. generator, the power actually taken for the whole being about 7·5kW.

As in the case of the Drive Oscillator, the anode circuit is branched, and we will deal with the input or H.T. branch before considering the H.F. circuits.

The source of supply in this case is a 3-phase generator delivering about 30kW at 440V. This is transformed to 10 000V and a bank of M.R.7a valves used to give full wave rectification on each phase. All the rectifier filaments for the whole set are supplied by transformers from a 15kW. 200 ~ 500V. alternator in this experimental set. Actually only about 5kW is taken. As a result of the 3 phases, the resulting D.C. has a comparatively small ripple, and no smoothing choke is necessary, only a 0·9 μF. condenser being used. The negative lead now goes direct to the magnifier filaments.

The positive lead would, in a normal choke control set, go through the speech choke and then divide into two branches for the main and modulator supplies. It is, however, a peculiarity of 5XX that separate H.T. supplies are used for the two branches. The two supplies are led through equal coils on a 1:1 transformer instead of a choke, and obviously the effect produced is identical ; an audio frequency change in the modulator anode current will induce a corresponding variation in the magnifier supply. It is, however, a useful feature that by winding the two coils in opposite directions on the core, the steady D.C. components of the two currents may be made to produce fields in opposition, so that their effects on the core cancel out. This absence of D.C. polarisation effects a considerable saving in iron. For a large set, such as 5XX, this is no small matter : even now the core of the choke is 5 in. × 5 in. cross section, the whole instrument being about 2 ft. × 3 ft. × 3 ft. over all. Each winding has an inductance of 24H so that a voltage of 3 000 is set up in it by an A.C. component of 24mA at 1000 ~

Across the valve side of the choke winding in the magnifier circuit is a condenser of ·0025 μF. capacity. The anode supply next passes through a radio choke of 3000 μH., consisting of single-layer coils on porcelain. The reaction of this to the radio-frequency current is 3 500Ω. The total current to the two valves is 2 400mA, giving an H.T. input of 24kW.

Turning now to the high frequency circuits ; to the grid is connected a condenser-leak combination consisting of a ·0046μF condenser paralleled by a leak of 7000Ω. This leak is rather interesting, being constructed of cloth woven with asbestos warp and wire weft. The D.C. component of the grid current being 200mA, we see that the leak depresses the mean potential to − 1 400V. Next follows the tuned input circuit. This comprises a condenser of ·000 55 μF consisting of one Moscicki tube, across a coupling coil of 1280 μH. The H.F. resistance of this circuit is kept fairly high, the normal current in it (H.F. component) being 3A.

The Output Circuit.

The H.F. anode circuit commences with a stopping condenser of ·005μF. Next comes the main coil, common to the H.T. and output circuits. This is a large coil of litz. wire on a skeleton framework. It is provided with anode and output taps, the latter including 450 μH. In series with it at the lower end are a variometer for fine adjust-

ment (not shown in the diagram), and the aerial coupling coil, which is of 30 μH. The whole of the inductance is bridged by a large condenser of ·001 5 μF, consisting of plates about 6 ft. × 8 ft. hung about 8 in. apart in air. The lower end of the parallel circuit thus formed is earthed, providing the return circuit to the filaments for the anode circuit.

The Aerial Circuit.

As will be known to our readers, the aerial at 5XX consists of a single sausage about 450ft. long and 400ft. high, with a similar lead-in. Its capacity is ·0035 μF, and the inductance of the order of 20-30 μH. (it has not been measured accurately). The resistance of the aerial circuit at 1600 metres is 12·5Ω, a rather high figure, due to the fact that (the aerial being actually over the works) a rather inefficient earth has to be used instead of a counterpoise.

The only loading is a coil of 280 μH, coupled to the output coil already mentioned; the aerial current is 40A, corresponding to an output of 20kW, the magnifier input being 24kW of D.C.

The Modulator.

This consists of a bank of four special water-cooled valves,. They differ from the valves used in the magnifier by having more open grids, their μ being 8 and R_a 2800Ω. The filament input is the same as that of the others. The filaments are fed from the same supply as those of the magnifiers.

The grid circuit comprises a dry battery of 150 volts, with individual tappings for the four valves. Next comes the secondary of the input transformer. This is of 10 : 1 ratio, the secondary having 20 400 turns. The remainder of the grid bias battery comes next, amounting to 850V, 1000 being provided in all. The D.C. grid current is nil, so that ordinary receiver 100V batteries are used.

The anode circuit gets its supply from a single-phase 300~ generator, giving 1000V. This is transformed to 10 000V and rectified by a full-wave rectifier, each half of which consists of three M.R.7a valves in parallel. The filaments are supplied in common with those of the other rectifiers. The resulting D.C. is smoothed by a bank of 21H chokes combined with one ·36 μF. condenser and three of ·18 μF. The anode lead then passes through the second winding of the transformer or double speech choke already described, and divides to the four valves.

An ingenious point here is the method of indicating separately the anode current of each valve. This is necessary, because no two valves are absolutely identical—hence the individual grid battery trappings. To avoid the necessity of four individual expensive milliammeters, only used when making adjustments on rare occasions, each anode lead has a 2-ohm resistance inserted in it, and an ordinary voltmeter can be switched across each, thus showing the current. The anode current to the four valves is the same as that for the magnifiers: 2400mA, or 24kW of power.

General Design.

It must, of course, be understood that the general arrangement of the set is purely experimental. In particular, the division of the power has been governed not so much by design considerations as by the generators available in the Marconi Co.'s research laboratory, in which the set is located. In fact, we believe that the one and only piece of apparatus specially made for the set was the double speech choke. This seems to function so well that it may be adopted as a final design, even if both modulators and magnifiers should be fed from the same supply. It is interesting to note the total power input to the set (the efficiency of conversion from A.C. to D.C. for the anode supplies is estimated at 80 per cent.):—

			kW.
Filaments:	6 10kW valves at 20V 40A	..	4·8
	2 M.T.7a at 12V 25A	..	·6
,,	A.C., 14 M.R.7a at 12V 25A ÷ ·8	..	5·2
Anodes:	Drive, 180mA		
	Magnifier 2400mA		
	Modulator 2400mA		
	4980 at 10 000V ÷ ·8	..	62.0
			72·6

An Experimental Determination of High Frequency Resistance.

By W. G. White.

The high frequency resistance of copper wires is a matter of considerable interest to experimenters. In this article, Mr. White describes some experiments on its measurement.

THE following notes describe an attempt to evaluate the high frequency resistance of straight, round, copper wires. The temperature rise of a wire carrying direct current is compared with the temperature rise when carrying alternating current ; thermo-junctions being employed for measuring the temperature.

The wire being tested was enclosed in an ebonite tube sealed at the ends as shown in Fig. 1. At the middle of the wire a thermo-junction was attached with the minimum of solder and brought out to a second junction, kept at a constant temperature, and connected in series with a galvanometer.

The circuit shown in Fig. 2 was employed to supply the test wire with current at radio frequencies. It was found that the circuit L_1, L_2, C_1, oscillated on a large number of different wave-lengths, and by adjusting the resonating circuit C_2, L_3 to any one of these frequencies currents of sinoidal wave

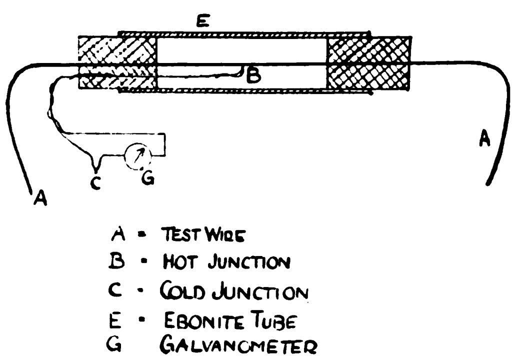


Fig. 1.

form could be obtained in this circuit. The wave form was checked by means of a cathode ray oscillograph.

It was found essential to "anchor" the galvanometer to earth by means of condenser C_3 to prevent the instrument attaining a high potential and also to eliminate trouble from body capacity.

With a steady alternating current passing through the wire, readings of deflection and time were taken and the results plotted as

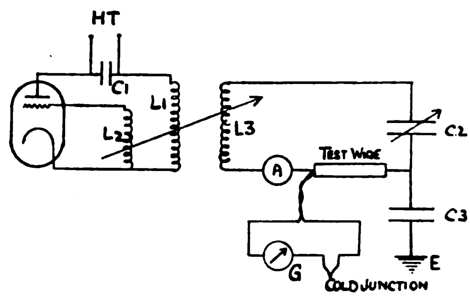


Fig. 2.

shown in Fig. 3. Similar curves were also obtained using direct current. If, now, an ordinate be drawn up from, say, the five minute mark, the points at which the curves are intercepted represent the deflection of the galvanometer after carrying a certain current for five minutes, and these deflections are a measure of the temperature rise of the wire :

If d = deflection of galvanometer
θ = corresponding temperature rise
R = resistance of wire under test, then
d is proportional to θ

Then $d \propto \theta$. But $\theta \propto I^2$, so that $d \propto I^2$.

Fig. 4 is typical of the results obtained with different gauges of wire and shows that the method gives reliable readings.

Referring now to Fig. 4, we see that any particular deflection of the galvanometer (say 4·2) can be obtained both with alternating current and with direct current, the actual values in Fig. 4 being 4·3 amps. and 6·45 amps respectively, and from these values we can compare the resistance of the wire to alternating current, with the resistance to direct current, thus :—

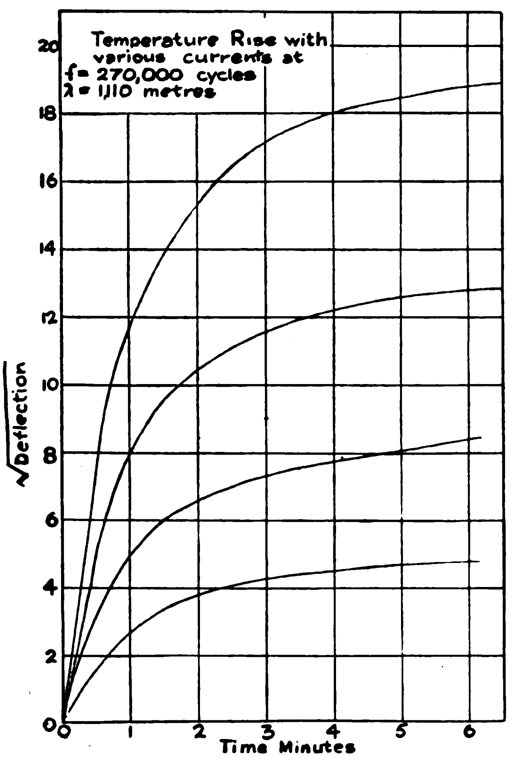


Fig. 3.

Let R_{dc} = resistance of wire to direct current.

R_{ac} = resistance of wire to alternating current.

I_{dc} = direct current producing the same temperature rise in a given time as an alternating current I_{ac}.

t = time, taken as 5 minutes in Fig. 4.

Then $I^2_{dc} \, R_{dc} t = I^2_{ac} \, R_{ac} t$

$$\therefore \frac{R_{ac}}{R_{dc}} = \left(\frac{I_{dc}}{I_{ac}}\right)^2 = m \text{ (say)}$$

The value of m obtained from Fig. 4, is :—

$$\left(\frac{6{\cdot}45}{4{\cdot}3}\right)^2 = 2{\cdot}25.$$

Hence, at a frequency of 270 000 cycles, corresponding to a wave-length of 1 110 meters, the resistance of a straight wire of No. 18 gauge is 2·25 times its resistance as measured with a Wheatstone bridge.

Curves similar to those in Figs. 3 and 4 were also obtained with three other frequencies, and the whole series were repeated with three other sizes of wire.

The Table shows the range of frequencies and wires tested, together with the results obtained from the graphs.

TABLE SHOWING VALUES OF m.

Wave-length λ		1740	1110	510	335
Frequency f		172 400	270 000	589 000	896 000
$\sqrt{f}$		415	520	769	946
SWG.	Diam.				
22	0·711	1·37	1·5	2·125	2·44
20	0·915	1·58	1·88	2·59	3·0
18	1.22	1·96	2·25	3·2	3·7
16	1·63	2·6	2·94	4·23	5·15

The next point is to determine the connection between the results obtained and the values of diameter and frequency, and with this end in view the factor m is plotted against the square root of the frequency, Fig. 5. These graphs are linear in form over the range tested although they must bend somewhere lower down so as to pass through the value of $m = 1$ at zero frequency, *i.e.*, the resistance is never less than its direct current value. From the figure it appears that the factor m is a function of the square root of the frequency and further the amplitude of the graphs appear to be a function of the diameter of the wire. This latter point is brought out more prominently in Fig. 6, where the factor m is plotted against the diameter of the wire in millimetres. These graphs must also pass through the value of $m = 1$.

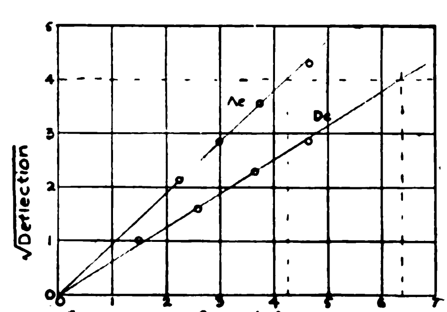
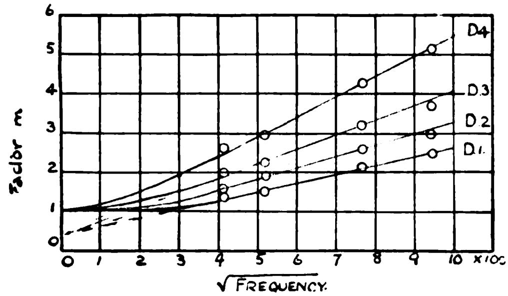


Fig. 4.



$D_1 = 0{\cdot}711\text{mm}$; $D_2 = 0{\cdot}915\text{mm}$;
$D_3 = 1{\cdot}22\text{mm}$, and $D_4 = 1{\cdot}63\text{mm}$.
Fig. 5.

From Figs. 5 and 6 it appears therefore that for the range tested the factor m may be defined by a simple expression of the form—

$$m = Kd\sqrt{f} + A, \text{ with } d \text{ in mm.}$$

Where K and A are constants.

The results of Figs. 5 and 6 are combined in Fig. 7 (full line), from which the value of A is found to be 0·4 and K = ·0309.

The subject of high frequency resistance has been investigated by Professor Morecroft but the results obtained by him do not appear to be quite consistent. For this reason it is hoped that although the results given here differ a little from those of Professor Morecroft, they may still be of some interest.

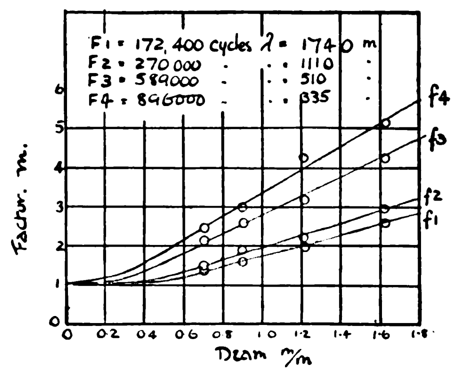


Fig. 6.

The copper and Eureka wires used for the junctions were of No. 36 S.W.G., but smaller wires would have been more suitable. These wires were carefully twisted together so that the e.m.f. induced in them by the oscillating circuit was neutralised as completely as possible. Without this precaution the galvanometer might easily have come to grief.

The test wire was enclosed in an ebonite tube in order to eliminate variations in air temperature in the vicinity of the wire. It was found that if the small wires tested were exposed to the air, movements of the hand or body were sufficient to cause the galvanometer "spot" to swing about over a wide range.

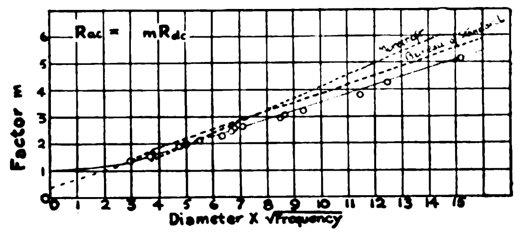


Fig. 7.

The method described above appears suitable for determining the high frequency resistance of heavy conductors used for transmitting inductances.

SUPPLEMENTARY NOTE.

(*By the Editor*, EXPERIMENTAL WIRELESS.)

It is interesting to compare Mr. White's experimental figures, and the empirical equation he derives from them, with the standard theoretical results and equations.

The complete equations for the ratio m are extremely complicated, but for values of $d\sqrt{f}$ (d = diameter in mm., f = frequency) greater than, say, 30, there are various approximations. Thus Fleming gives

$$m = {\cdot}033d\sqrt{f} + {\cdot}3 \qquad \ldots \qquad (a)$$

Morecroft does not give an equation, but from his curves one may find, for $d\sqrt{f}$ greater than 25 to 30

$$m = {\cdot}041\, d\sqrt{f} - {\cdot}55 \qquad \ldots \qquad (b)$$

While in the admirable Circular No. 74 of the Bureau of Standards of the U.S.A., "Radio Instruments and Measurements," we find a set of tables from which we can derive, for $d\sqrt{f}$ greater than about 30

$$m = {\cdot}033\, d\sqrt{f} + {\cdot}5 \qquad \ldots \qquad (c)$$

To Fig. 7 of the paper we have added dotted lines showing the results to be expected from formulæ (b) and (c). As would be expected from the equations in both cases, the values are higher than those obtained in Mr. White's experiments. Not knowing in exact detail the precautions adopted in the tests, we cannot say why.

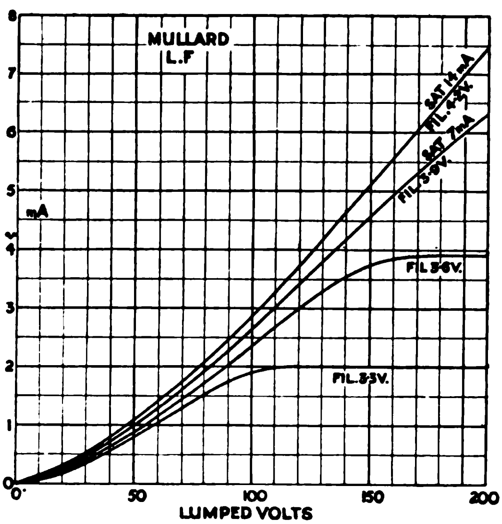
It will, of course, be realised that these equations apply only to straight wires, not coils, and only to copper wires. In the case of wires of other metals, not only is the resistance changed, but also the value of m, the ratio of H.F. to D.C. resistance.

Valves and Valve Testing

With three new productions as examples.

IN describing the results of one's tests on valves, one is naturally anxious to give the fullest possible information, while at the same time the information must be conveyed in a concise form. The usual series of curves, showing current in terms of grid bias for various H.T. voltages, is insufficient, as they do not give any idea of the effect of filament current. A series of three or four such sets would take too much space.

What then is needed ?



Direct information as to the μ, or voltage amplification, is useful for obvious reasons. But the anode impedance, R_a, is also highly important, as the choice of intervalve transformers or resistances to use depends on it. It is easily proved that the performance of a valve for transformer-coupled L.F. work, *with a transformer chosen to suit it,* is proportional to $\frac{\mu^2}{R_a}$, so this figure is useful. Also, for L.F. work, especially for use with the loud-speaker, it is necessary to know the saturation current, from which one can estimate the amount of power which can be handled without noticeable distortion. Since this varies with the filament heat, it is useful to have it (and the other constants mentioned) for various filament voltages. The filament current is also an obvious necessity. Lastly, in order to get the proper H.T. and grid voltages to use, one needs a characteristic for each filament voltage. But the usual set of several is not necessary. The result can be shown in *one* curve of the Eccles "lumped" type, if the μ is given. The Eccles lumped characteristic gives anode current for various values of *combined grid and anode voltage,* got by taking the anode voltage and adding μ times the grid volts (subtracting if the grid volts are negative).

It follows that if the lumped curve shows 2mA, say, for 100 lumped volts, then if $\mu=8$ this current will be got by 0 on grid and 100 on anode, or +2 on grid and 84 ($100-2\times8$) on anode, or — 3 on grid and 124 on anode. So that from each lumped curve the reader can make, if he wishes, a complete set of either anode-volt or grid-volt curves.

Lastly, it is interesting to know, for comparison with other valves, what one may call the "filament efficiency": milliamps of output per watt input to the filament.

This method then will be adopted in E. W. & W. E. (until some even better one is found) of giving maximum information in minimum space when describing new valves. Here follow the results on three recently to hand.

The New Mullard H.F. and L.F. Values.

These are put forward in the belief that the bright valve, with its robustness and comparatively low price, has still a long life before it. As regards the filament input they resemble the old type of R and similar valve; but the electrodes have been redesigned in the light of later knowledge, and a considerably increased performance obtained.

A free arched filament is now employed, with U-shaped grid and anode. In the actual valves it is hard to see any difference between the L.F. and H.F. grids, owing to the

magnesium deposit. Presumably the H.F. grid is of heavier wire. The "open" end of the U, below the filament, is also partly closed up in the H.F. The two are distinguished externally by a narrow coloured band round the bulb, red for H.F. and green for L.F. Another new point in construction is the use of a moulded ebonite cap without metal, said to give considerably less capacity.

As regards performance, the accompanying curves show lumped characteristics. In both cases the saturation current at 3·9 volts is about the same as that of a good "R," while at 4·2 volts it is much better. The H.F. valve has, throughout, a lower μ and R_a and a higher output than the L.F.; it has also a very slightly higher power amplification co-efficient. In fact, it would be the better valve of the two for L.F. but for the fact that for L.F. work one needs a fairly straight characteristic. It will be seen that the L.F. curve for 4·2 volts straightens out nicely at about 4mA, 100V., while the H.F. only begins to straighten at 200V, 8·6mA.

H.F.

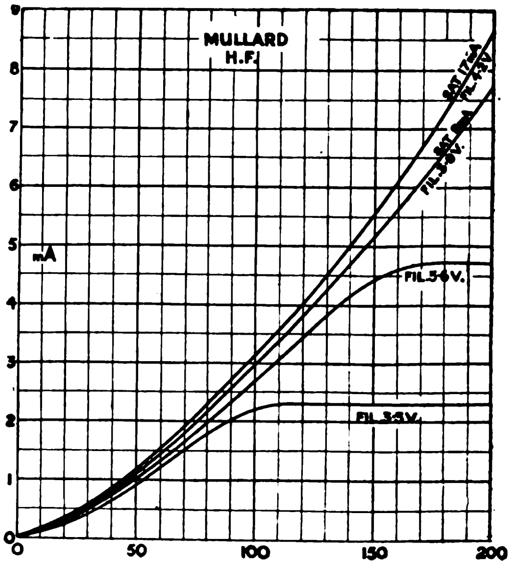
Fil. Volts. E_f	Fil. Cur. I_f	Sat. Cur. I_s	Anode Impedance. R_a	Voltage Ampli. μ	Power Ampli. $P\left(=\frac{\mu^2}{R_a}\right)$	Filament Efficiency $=\frac{I_f}{\text{Watts.}}$
V.	A.	mA.	O.			
3·3	·66	2·3	31 500	7·7	1·88	1·05
3·6	·69	4·7	28 500	7·5	1·97	1·9
3·9	·73	9·0	25 500	7·3	2·08	3·15
4·2	·76	17·0	23 500	7·0	2·09	5·3

L.F.

Fil. Volts. E_f	Fil. Cur. I_f	Sat. Cur. I_s	Anode Impedance. R_a	Voltage Ampli. μ	Power Ampli. $P\left(=\frac{\mu^2}{R_a}\right)$	Filament Efficiency $=\frac{I_f}{\text{Watts.}}$
V.	A.	mA.	O.			
3·3	·66	2·0	38 000	8·3	1·80	·92
3·6	·69	3·9	34 000	8·1	1·94	1·58
3·9	·72	7·0	30 000	7·7	2·00	2·5
4·2	·75	14·0	27 000	7·3	2·00	4·32

The Performance of the New Mullard Valves.

The H.F. valve is recommended as a detector, on account of its larger grid current at zero grid volts. This would hardly seem so very important, as detector performance would appear to depend really on the sharpness of curvature at the bend of the grid current curve. This was not tested, but judging by the makers' curves both valves would seem likely to do well. About 60-70V on the plate brings the steep part of the anode current curve well over the bend of the grid current curve. A 3-MO grid-leak is recommended.



For loud-speaker work, reckoning on a grid swing of, say, 3V each way, the L.F. valve should do well if kept up to 4V or over on the filament. One might use the 4·2 volt curve from 3mA upwards, from which point it is fairly straight. The swing of 3V on the grid equalling 21V on the anode, we could use the 120-volt point to work on (=3·8mA). To allow for 3V of grid swing, 4V of bias would be advisable. As the lumped voltage is to be 120, this gives us 120+4×7=148, or, say, 150 volts as a good working voltage. This was found correct on test: we do not agree with the makers' suggestion that the L.F. valve will allow of L.F. amplification without grid bias.

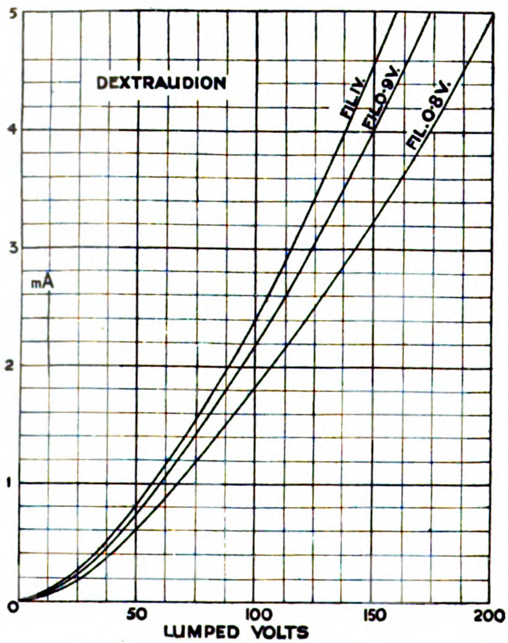
Taken altogether, the two valves are well worthy of the makers' high reputation.

The Dextraudion.

The race to decrease the filament consumption of receiving valves is producing some surprising results, considering that it is only about a year or two since the dull emitter was only an experimental proposition. All that is wanted now is a valve

with negative consumption, which will return energy to its filament circuit as well as to its input.

This has not yet arrived, alas! But we have just been testing a valve rated to consume ·1 watt, or just about half the power of the standard 60mA type. This is the Dextraudion, marketed by The Economic Electric Co. It is an oxide-filament valve, apparently—at any rate the filament works at the same dull red as in that type. It is to be noted that it costs only 21s.



The electrodes are of the same type as in the earlier E.E.C. valve, forming the top and sides of a rectangular box. They are, however, smaller.

On actual test, we found the filament consumption rather above the rating: as will be seen from our Table, it varies from ·125 to ·155. However, the valve works quite well at ·8 volt, so that the watt rating is correct.

The voltage magnification is curious in being, as far as we could tell, constant over the whole range tested. We found, however, quite a difficulty in testing, as the anode current showed a tendency to "creep." On increasing the anode voltage, for example, the current would jump to a higher value and then go on increasing slowly for some time.

	Fil. Volts. E_f	Fil. Cur. I_f	Sat. Cur. I_s	Voltage Ampli. μ	Anode Impedance. R_a	Power Ampli. $\frac{\mu^2}{R_a}$
	V.	A.	mA.		O	
DEX-TRAUDION	·8	·125	—	7·4	45 000	1·2
	·9	·135	—	7·4	35 000	1·56
	1·0	·145	—	7·4	30 000	1·8
	1·1	·155	—	7·4	29 000	1·85

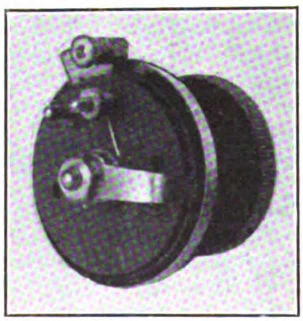
This is connected, we believe, with the fact that the valve is distinctly soft. We could find no signs of a saturation current: but on raising either the grid or the anode volts so that the current rose much above about 5mA, the valve blued up distinctly: the space is so small that it was hard to say exactly. Since any ionisation is likely to damage a coated filament very quickly, we did not like to force the valve.

It is likely, on this account, to make a good detector, but as we have not yet found a quantitative method of expressing the detecting properties of a valve, we cannot express an opinion, except that it seemed to work very well.

The curve for 1·1V on the filament was practically coincident with that for 1V.

A GOOD VARIABLE GRID-LEAK.

Our readers frequently inquire whether we know of a satisfactory variable grid-leak, and we have pleasure in reporting on one which, at any rate on a preliminary test, gives excellent promise.



This is made by J. Anderson, 60, Garfield Street, Watford, and the general arrangement is that of a miniature filament rheostat, with the coil replaced by a stick about $\frac{1}{16}$ in. diameter of some black substance—nature unknown. We tested it at the extremes of its travel, and at three other points about equally spaced, with the following results in megohms:—

Position:	min.	$\frac{1}{4}$	$\frac{1}{2}$	$\frac{3}{4}$	max.
Resistance:	·18	1·35	3·25	6·5	9·7 M O.

Results consistent to 2 per cent. were obtained the next day; but whether tests over a long period would be equally good we cannot, of course, say. We are inclined to recommend our readers to try.

The Problem of High-tension Supply.—IV.

By R. Mines, B.Sc. (Eng.).

(*Continued from August issue, page* 652.)

Impulse Generators.

In view of the requirement of a supply of power at a steady high potential, it would appear that apparatus coming under this heading would be the last kind to use if this result is to be secured. As the name implies, such generators produce successive pulses or peaks of potential, which with a suitable load are followed by corresponding rushes of current. These impulses follow one another usually at a steady rate, the frequency depending upon the design of the apparatus.

Nevertheless under the heading, "Use of an A.C. Supply," have been described methods in which the uni-directional power supply is in the first instance available only in pulses of short duration relative to their time period; therefore although the impulse generator as a source of high-tension power may prove to be a degree worse than the "rectified alternating supply," the difficulties involved in its use are of the same nature and are not insurmountable.

The Induction Coil.

Most experimenters will have had personal acquaintance with this piece of apparatus, so there will be no need to describe its construction here. In the common method of using the device (invented by Mason and improved by Ruhmkorff) power from a D.C. source, usually a battery, is applied to the primary winding, and in the primary circuit is included an essential auxiliary device, the Interrupter, which alternately makes and breaks this circuit. As a result of the periodic interruption and re-establishment of the primary current, there are alternations of growth and decay of the magnetism in the iron core, and this by ordinary induction, as in a transformer, gives rise to pulses of electromotive force in the secondary windings; these pulses correspond to the alternate making and breaking of the primary circuit and therefore occur alternately in opposite directions. Further, due to the inductance of the primary winding with its iron core, the growth of the current on making the circuit is necessarily comparatively slow, whereas the stoppage of the current on breaking the circuit can with a suitable design of interrupter be made exceedingly sudden.

We thus arrive at the characteristic feature of the Induction Coil as an impulse generator, that the pulses in one direction are very intense and of short duration, while those in the opposite direction (known as "inverse") last for a considerable portion of the cycle and are comparatively weak.

Evidently the induction coil constitutes a simple and useful source of power at a high potential, and since early days it has proved its utility for exciting discharge tubes and similar experimental work. In its modern powerful forms it is still one of the important means of supplying large X-Ray tubes; but in this work it is found advisable to combine it with a rectifier device, unless a "self-rectifying" tube is being used, because in the X-Ray tube, "inverse current" involves heating of the tube without any corresponding useful production of X-Rays.

If such an apparatus is to be used for feeding power against a steady P.D. then a rectifier becomes an essential part of the equipment, just as with the A.C. transformer previously considered; otherwise power would flow backwards all the time that the varying P.D. of the generator falls below the steady P.D. of the load circuit, and especially while the inverse pulse is occurring. The simplest arrangement is to use a single rectifier, as shown in Fig. 1A of our Part II. in the July number, in which case the connections will be arranged so that it is the intense pulse (due to breaking of the primary circuit) that is utilised. (It would be possible, but uneconomical, to use the inverse pulse instead.) We have seen

also how by using two or four rectifiers (see Figs. 2A and 3, July number) it is possible to use both the half-waves of the A.C. input; for with a true A.C. supply the half-waves are similar in magnitude and duration. On the other hand, the induction coil, as above described, does not permit the use of both pulses, because of their dissimilarity.

Modifications of the Induction Coil Method.

In the classical method above described, the essential desideratum is always to make the breakage of the primary circuit as sudden as possible, as this gives the maximum peak value of the secondary potential for a given size of coil. Now a heavy current flowing through an inductive circuit is the most difficult kind to interrupt, and much research has been devoted to the development of interrupters to perform this task.

This problem may be attacked however from quite a different point of view—for example, by controlling the cyclic variation of the inductive energy in the primary circuit. Wilson's* first attempt in this direction was along the following lines:—

Energy from the supply was stored in a separate inductance; this inductance was coupled to an oscillatory circuit of long periodic time, so that when the supply circuit was interrupted, the inductive energy was transferred to a condenser relatively slowly. Subsequently a third brush on the interrupter short circuited the inductance, so that the condenser discharged with extreme rapidity through the primary winding of the induction coil. This rapid discharge entails a very sudden growth (instead of decay) of the primary current and so a high peak of potential on the secondary, combined with an almost sparkless interruption on the primary, two conditions which with the old method were incompatible.

This system had the disadvantage of giving a very low pulse frequency, due to the complicated cycle of operations that had to be controlled by the interrupter switch, and in addition the operation of the switch was by no means sparkless. A new method* was evolved therefore, one of the aims of which was to reduce the inductive energy to zero at the instant of rupture of the primary circuit, so that there would be no current to "interrupt" and hence little tendency to spark. This time the energy from the supply is stored in a large condenser ("C" in Fig. 1A). The rotary interrupter, when properly adjusted for timing, breaks the supply circuit at the instant when the charging current flowing from the supply through the primary p of the spark coil, and so the inductive energy in this primary, is zero. The condenser has shunted across it an auxiliary inductance L, and through this it begins to discharge as soon as the supply is disconnected. The discharge over-

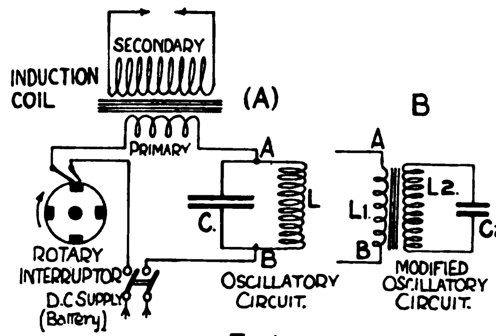


FIG. 1.
[WILSON, 1922]

shoots itself, due to the fly-wheel effect of L, in other words, the circuit LC oscillates at its own natural frequency. The interrupter reconnects the supply as soon as the condenser has reversed its polarity, so that a further pulse of current flows from it in the correct direction to "boost up" the oscillation in the circuit LC. The action is exactly similar to the building up and maintenance of the swing of a clock pendulum by the "impulse" delivered through the escapement.

Obviously it is necessary for the interrupter to be driven at a constant speed, which must be closely adjusted to give the required condition of resonance with the circuit LC. The drive may conveniently be an electric motor running from the battery supply; but if instead a synchronous motor is used, drawing power from the oscillatory circuit (preferably through a miniature transformer), then this circuit fixes the speed to suit itself, thus eliminating the necessity for a critical

* W. H. Wilson. *Jour Röntgen Soc.*, p. 64 (1911).

* W. H. Wilson. *Jour Röntgen Soc.*, 18, 143 (July, 1922).

speed control, requiring adjustment with every change of battery P.D. or other condition (such as heating of the apparatus). There is the difficulty of starting the synchronous motor (running up to the synchronous speed), but with a small machine it is possible to arrange for this to be done by hand.

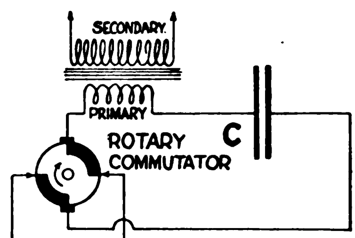
As a result of the resonance established in the circuit *LC*, a high value of alternating P.D. appears between the points *A* and *B* (Fig. 1A); and during the period of connection of the supply by the rotary interrupter, this P.D. is in such a direction as to help the supply P.D. in sending pulses of current through the primary *P*. These pulses are, therefore, many times larger than would obtain if the circuit *LC* were absent, or were not resonating with the interrupter frequency.

The more intense pulse of E.M.F. on the secondary occurs at "make" of the interrupter and not at "break," since as a result of the resonant P.D. of the circuit *LC* the growth of the primary current is more sudden than its decay: for the same size of coil this pulse is of the same order of magnitude as, but lasts much longer than, the intense pulse obtained at "break" of the primary current with an ordinary interrupter. Thus with Wilson's arrangement an induction coil gives much more power, while the moving part of the auxiliary equipment, the interrupter switch, is simpler and trouble-free; the apparatus is no improvement in the matter of "inverse current," a rectifier must still be used to suppress it if a steady D.C. output is required.

One should note here, however, that in practice a modification is made to the primary circuit. Owing to mechanical limits to the speed of the interrupter and the number of segments it may be fitted with, the frequency at which the circuit must oscillate is necessarily low, and so both the inductance *L* and the condenser *C* must be large. It is found more convenient to substitute a step-up transformer for the inductance as shown in Fig. 1B, and the condenser, which now need be of only a small capacity, is connected across its secondary. With this arrangement it is the secondary circuit that oscillates; but due to the close coupling with the primary, the effect on the induction coil primary is the same.

The Induction Coil as a Transformer.

We see that in the methods so far described the high-tension output consists of two dissimilar pulses, only one of which is useful; it is natural to inquire whether it is possible to secure symmetry in the output wave-form, *i.e.*, to make the two pulses alike as with an A.C., for by this means an increased power output is obtainable from the same size of apparatus. A suggestion for securing this result, is that the input current should be reversed in direction through the primary winding of the coil, instead of being merely started and stopped by the rotary switch. The amplitude of the change of magnetic flux in the iron core which occurs at each operation of this switch is therefore double its previous value, and it should be possible to obtain twice the energy from the secondary at each pulse; further, the symmetry of the pulses enables both to be used, so the actual gain should be four-fold.

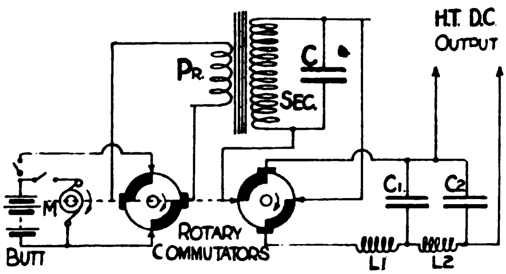


F2
THE INDUCTION COIL AS A TRANSFORMER

Now the problem of reversal of the primary current may be attacked in a manner similar to the problem of its interruption. Fig. 2 shows a condenser connected in series with the primary winding of an induction coil, the combination being connected to a D.C. source of power through a rotary reversing switch or commutator instead of an interrupter. This switch is preferably driven at constant speed by an electric motor.

With the commutator in the position shown, a charging current flows from the supply until the primary and the left-hand condenser plate are charged to the potential of the positive pole of the supply, and the right-hand plate is at the potential of the negative pole. After a quarter of a revolution, however, the commutator reverses the

connections; the condenser therefore discharges and then recharges in the opposite direction. The corresponding current rush is in the opposite direction in the primary and condenser circuit, but due to the reversed connections at the commutator it is in the same direction in the supply circuit. Similarly, when the commutator has completed half a revolution, the condenser charge reverses, again accompanied by a current rush through the primary winding, and so the cycle repeats itself. Now in this method again we have an oscillatory circuit, composed of the inductive primary and the condenser; and if the speed of the rotary switch is adjusted so that the frequency of reversal is equal to the natural frequency of this circuit a condition of resonance will be established.



F.3

R BARTHÉLEMY'S Stato-Mechanical Converter

Under this condition the electrical oscillation builds up to a maximum, and approximates to a sinusoidal wave-form; thus an amplified alternating P.D. appears across the primary terminals, which may be regarded as assisting the small supply P.D. to pump large current pulses through the primary, as occurs with Wilson's apparatus. The current drawn from the D.C. supply is of course uni-directional, but is in pulses corresponding to each half-wave of the primary oscillation. The output P.D. appearing at the secondary terminals of the induction coil is a symmetrical alternating P.D., and the problem of its use for providing a steady high-tension supply may be attacked on the lines laid down in the section on "Use of an A.C. Supply." In this connection it may be remarked that the method invites the use of a mechanical rectifier (rotary type), for this may be mounted on the same shaft with the commutator in the primary circuit.

As with Wilson's apparatus, there is a mechanical limit to the frequency that may be attained, involving an unduly large condenser, especially since the inductance available in the primary is a fixed quantity. A similar way out of the difficulty presents itself in this case, with the added advantage, however, that there is no necessity for a separate step-up transformer to be used—the small condenser may be connected direct across the induction coil secondary. With this arrangement therefore the two stages of amplification of the P.D. occur both in the same circuit—the one due to the stepping-up by the induction coil functioning as a transformer, the other due to resonance in the secondary circuit.

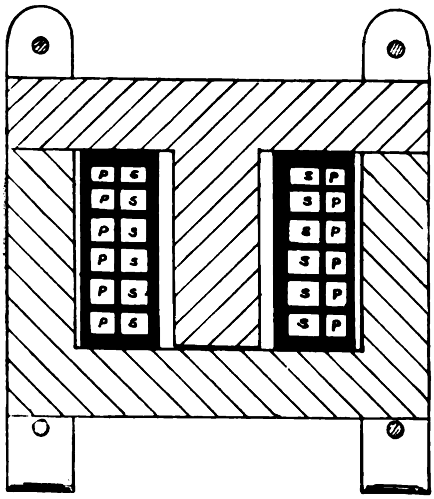
This modified arrangement, combined with a mechanical rectifier, is the "Stato-Mechanical Converter" recently developed by R. Barthélemy.* Fig. 3 shows the complete apparatus, as designed for supplying the high-tension power for a 3-valve radio transmitter. The complete converter (built in 1918) was contained in a rectangular box occupying about 1/9 cubic foot. It was operated from a 12-volt storage battery, and supplied 50 to 60mA. at 350V with an overall efficiency of about 60 per cent. The electrical conditions necessary to secure sparkless operation of the commutators are dealt with in detail in the original paper. With 25A being drawn from the battery, there was no sign of current flow at the low-tension brushes except some rise in temperature. The filter shown had inductance of 100H. and condensers of 1μF., and was stated to render the P.D. wave sufficiently pure for use on radio telephony.

* *Rev. Gén. d'Elec.*, 10, p 659 (Nov. 12, 1921). *R. Barthélemy* . . .

A New R.I. Transformer.

The new L.F. Intervalve transformer which has just been put on the market by Messrs. Radio Instruments, Ltd., is interesting, apart from any other things, because it has been designed to supersede a type of which 250,000 have been sold with satisfaction during the last two years.

According to the information supplied by the maker, much trouble has been taken in the new type to get the best performance possible consistent

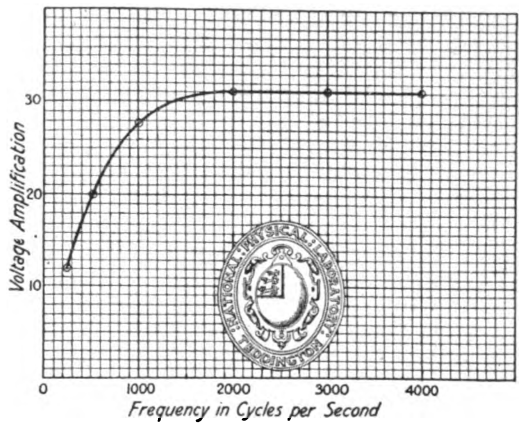


with robustness and a reasonable selling price. There must necessarily be a compromise here, for theoretical design calls for larger windings than can be put on if fairly heavy wire is to be used. According to Messrs. Radio Instruments, the primary, of 3,000 turns, gives 11H, and the secondary, of 12,000 turns, 160H. (It is curious that there should be such a distinct divergence between the ratio of inductance and the square of the turns ratio.)

The performance, both as regards amplification and distortion, is well shown by the N.P.L. curve reproduced. Presuming that, as usual, the N.P.L. tested on a valve with a μ of about 8·3, we see that at all frequencies above 2,000 the step-up is 3·75, while there is less than 20 per cent. falling off—about the smallest that can be noticed—at frequencies over 800.

It is to be noted that a special effort to reduce self-capacity has been made, by winding both primary and secondary in sections, the arrangement being according to the sketch reproduced. By this means the (presumably total) self-capacity has been reduced to $18\mu\mu F$, a quite exceptionally low figure.

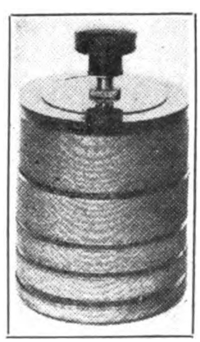
Tested on actual telephony, the results were very good. We have adopted as standards on our set various transformers of well-known commercial makes which represent first-class current design, and the R.I., when tested against these for strength, showed the following results: after a crystal 1·2 × standard; after an ordinary valve of 30,000 ohms anode impedance, equal; after a power valve of 6,000 ohms, 1·2 × standard. The tone



was excellent throughout. Two points needed care: first it is important to find the right connections by trying the windings reversed; they are made unusual by the fact that the secondary is inside the primary: second, owing to its very low self-capacity, it is very sensitive to capacity across the secondary, and can be given any desired tone in this manner. We found a small condenser an improvement.

A Ready-made Tapped Coil.

Those amateurs who at any time want a neat tapped coil all ready for panel mounting may care to remember the "Success Tuner" of Messrs. Beard & Fitch. Our illustration shows the general design; it is of the one-hole fixing type. An 11-point switch is fitted at the back end, operated by a central spindle: the switch is a good mechanical job.



Only the extremes of the inductance were tested: on stop 11 it was $5800\mu H$, on stop 1, $80\mu H$. In the latter position the self-capacity was approximately $45\mu\mu F$, so that the instrument with a ·001 variable condenser, will tune from 135 metres to 4750. H.F. resistance was not measured, but should be low; the wire appears to be 28 S.W.G. D.C.C.

The instrument is priced at 21s., which seems high. There is, however, a good deal of work in it.

Correspondence.

Letters of interest to experimenters are always welcome. In publishing such communications the Editors do not necessarily endorse any technical or general statements which they may contain.

Electrolytic Rectifiers.

MONSIEUR LE REDACTEUR D'"EXPERIMENTAL WIRELESS,"—Faisant actuellement une étude détaillée des redresseurs électrolytiques, j'ai lu avec un intérêt particulier l'article de Mr. E. H. Robinson, dans le numéro du mois d'Août, sur le fonctionnement de ces redresseurs aux fréquences élevées.

Je puis vous signaler que cette question a été étudiée par Zenneck (*Elektroteknische Zeitschrift*, 24 mai 1923, t. XCIV., p. 501), ainsi que par A. Gûnther-Schulze, R. Lindeman et E. Alberti, qui ont trouvé que l'effet de soupape se manifeste encore à la fréquence 3.10^5 et qui ont conclu que, puisque l'effet redresseur existe encore à ces fréquences élevées, c'est qu'il ne s'agit pas de séparation ou de formation d'ions, mais seulement de phénomènes électroniques.

Dans un précédent article, Mr. E. H. Robinson a trouvé tout à fait "hopeless" l'emploi du borax comme électrolyte pour ces redresseurs. Des essais que j'ai faits à ce sujet il résulte que *certains* borax ne donnent, en effet, *aucun* redressement; *certains autres* donnent un redressement médiocre; *d'autres* enfin donnent un redressement *excellent*. Ces différences dans les résultats sont probablement dûes à divers degrés de pureté du sel employé. Il faut remarquer, à ce sujet, que la plupart des Américains qui emploient avec succès le borax, spécifient qu'ils se servent de "20 *Mule Team Borax*," ce qui est probablement une marque de borax particulièrement purs.

Recevez, Monsieur le Rédacteur, mes bien sincères salutations.

DR. PIERRE CORRET (8AE).

(*Translation*)

As I am actually engaged in a detailed study of electrolytic rectifiers, I have read with particular interest the article by Mr. E. R. Robinson, in the August issue of EXPERIMENTAL WIRELESS, on the performance of these rectifiers at high frequencies. It may be noted that this question has been studied by Zenneck in *Electroteckniscche Zeitschrift* of May 24th, 1923, Vol. XCIV., page 501, also by A. Gunther-Schulze; R. Lindeman; and E. Alberti; who find that rectification is still possible even up to frequencies of 300 000. They conclude that in view of this fact, rectification cannot be due to the separation or the formation of ions, but is essentially an electronic phenomenon.

In an earlier article Mr. Robinson has found the use of Borax "hopeless" as an electrolyte in these rectifiers. My own experiments on the subject show that certain samples of borax certainly give no rectification. Others, however, give fair results; and others again perform excellently. These differences are probably due to the varying degree of purity of the borax employed. It should be noted that the majority of the successful users of borax in America use the brand known as "20 Mule Team" Borax. Presumably this is a particularly pure brand.

SIR,—I was very interested in E. H. R.'s account of his experiments with electrolytic rectifiers at high frequencies, but although I have never worked at this branch of the subject myself, I must confess to a difference of opinion with him about the operation of the rectifier.

That the efficiency of an electrolytic rectifier falls off with increase in the frequency of the alternating current is an established fact, but I cannot agree with E. H. R. in explaining this fact by the time taken, or the work done, in forming or destroying an oxide film. In the light of modern work such an explanation is untenable; the reasons for this are too long and numerous to be given here, I can only refer those who are interested to the *Transactions of the Faraday Society*, Vol. IX, p. 266, or to my book on the Electrolytic Rectifier.

The decrease in efficiency with increase in frequency can only be explained by the capacity of an aluminium anode, and as E. H. R. has pointed out, this capacity is considerable. Therefore the capacity must be kept down; E. H. R. has accomplished this by using very small anodes, but there is another method of reducing the capacity. An aluminium anode has a smaller capacity in fused electrolytes than in aqueous electrolytes, therefore a rectifier with a fused salt as electrolyte should be more efficient on high frequencies than one with a solution. A. Gunther Schulze and E. Alberti (*Phys. Zeits.* 23, p. 188-191, 1922) by using fused potassium nitrate as electrolyte, have rectified currents of 300 000 cycles per second.

N. A. DE BRUYNE.

Charges on Aerials.

SIR,—I noted with interest the correspondence in your August issue *re* the charging of aerials from atmospheric electricity.

Mr. Bligh suggests the use of steel points for a spark gap, but I should like to point out the disadvantage of these. My experience has been as follows. A *steel* point gap was installed and adjusted with a very narrow gap, a very small fraction of a turn of the threaded rod being required to short-circuit the aerial to earth. The gap was then left unattended for some months. One evening signals were noisy and intermittent and eventually ceased. A fault in the receiver was immediately expected and looked for but a long search failed to reveal any loose connection. On inspection it was found that the steel points had rusted and shorted across, thus effectually stopping reception. Brass is also liable to corrosion, although not so fast. Nickel seems the best metal; in fact, high-class work which calls for similar conditions is always done in solid nickel.

As mentioned by Mr. Bligh, spark gaps *do not* lead to inefficiency if properly constructed, and they are the only satisfactory way of protecting the aerial, especially when experimental work is being carried out on atmospheric effects which calls for the use of an aerial when in the normal way it should be left alone! Another interesting point in connection with the leakage of the charge from points. It is a well-known fact that a pointed conductor will soon lose its charge by leakage and it occurred to me that a well-insulated aerial with all the ends tucked away and finished off will be a greater source of danger than one in which loose ends are left, or one such as is occasionally seen with wire "spider-webs" attached to it from which the charge would rapidly leak, particularly if there are any wet trees, etc., in the vicinity.

H. A. CLARK.

Telephony Reception.

SIR,—I was particularly interested in Mr. H. J. Neill's "Telephony Reception" in your this month's issue, the subject being one in which I am—it is not too much to say—engrossed. Quantity—with *quality*.

I would esteem it a favour to have a little further information on one point. In the matter of air-space inductance, the superiority of which is easily demonstrable, on page 632, col. 1, Mr. Neill speaks of "the *closed* circuit inductance . . . wound on a hexagonal frame 6 ins. across. . . ." I have used a similar A.T.I. (on the "broadcast" wave-band of course) for a long time now, but—my difficulty is a practical one—I am still seeking a really good method of working a loose-coupled circuit with inductances of the type mentioned. Without occupying too much of your space, would Mr. Neill tell us—I feel others would be interested—how he arranges the coupling between primary and secondary and the proportions of the two coils, and if possible the shape and nature of the reaction coil shown associated with the C.C.I. in the diagram? I can only express my sincere thanks for the article as a whole—thoroughly worthy of the character of your publication. That is saying, in my humble opinion, a very great deal. Thanking you both in anticipation.

H. MASON.

"A Universal Meter."

SIR,—With reference to the article on "A Universal Meter" in the July issue, I am afraid Mr. Dyson has neglected an important consideration in stating that the instrument has an even scale. The condition for this desirable feature is that the field in which the coil swings shall be uniform and *radial*. This is secured in commercial instruments by the use of curved pole-pieces

on the magnet and by fixing a cylinder of soft iron inside the coil, which is necessarily wound on a hollow framework instead of a hollow former. Incidentally this decreases the air-gap and makes the instrument more sensitive.

In the arrangement described by Mr. Dyson the field would be parallel, and the law of the instrument :—

$$C = K \times \frac{\theta}{\cos\theta}$$

Instead of :—

$$C = K\theta$$

If the latter law is assumed, an error of about 13 per cent. will be introduced at each end of the scale, if the middle is correct, assuming the whole scale to be 60°, while if it extends to 120°, as the writer appears to indicate, the error will be as high as 50 per cent. This presumes that the control is torsional: actually a bifilar suspension is employed which tends to modify further the calibration, but owing to the closeness of the two wires, the control is almost entirely torsional.

I do not wish to suggest that such a meter is useless, but it would need calibrating at more than one point.

E. LESTER SMITH.

A.D. Cells.

SIR,—We note that in your issue of August, on page 647 (dealing with High-Tension Supply), it is stated that our A.D. Cells were invented by Fery, and are being marketed in this country under the name of A.D. Cells.

May we point out to you that A.D. cells were invented by us, and that they will shortly be manufactured in large quantities at our new works at Portslade, Sussex.

Will you kindly correct this wrong impression in your next issue.

LE CARBONE.

Spark Jamming.

SIR,—In your remarks concerning the reply of the Post Office officials about the question of spark jamming of broadcasting, I believe you lay rather too much emphasis on the poor selectivity of broadcast receivers. I would venture to say that very little can be done to eliminate spark jamming if retroaction is already in use. It is well known that the decrement of a receiving circuit approaches zero when the set is on the point of oscillation, as it usually has to be when reception is over a long distance. In such a case, any jamming will be due almost entirely to the transmitting stations large decrement.

The writer recently tested a super-heterodyne receiver at 3½ miles from 2LO, and using a good indoor aerial and low resistance earth 2LO could be cut out if the receiver was detuned to a frequency differing by 5 kilocycles. That is to say, it was possible to receive Le Petit Parisien on a loud-speaker without trace of 2LO when that station was working on a wave-length midway between 5WA and 2LO.

This same receiver was later used in Cornwall and found no more selective than a standard set with two stages tuned H.F. and simple circuit tuning. FFU working on ±600 could be read when 6BM or 5WA were tuned in and all the French trawlers (who are responsible for 80 per cent. of the spark jamming in this region) interfered just as much as on the standard set operated just off point of oscillation.

The only way we have available for increasing selectivity is to be found in the conjoint use of a frame and an open aerial to give heart-shaped reception.

I hope this letter is not too long, but I feel that those who pride themselves on being able to cut out their local station at 3 or 4 miles should realise that this is not the same thing as eliminating a flatly tuned spark station.

R. H. P. COLLINGS.

A French Short-Wave Transmission.

SIR,—I have been asked by F8ÉK to inform the English Wireless Press that he transmits telephony and CW every Wednesday from 9 p.m. till midnight on a power of 50 watts and on wave-lengths between 80 and 150m. His QRA is, Mons. Ateliers Lemouzy, 42, Avenue Philippe-Auguste, Paris (XIe).

I trust the above is quite clear and will be of interest to you.

C. L. WARD.

Recent Wireless Publications.

Figures after the title of each publication indicate Volume and Number of Publication containing the article. Where only one number is given, this indicates the serial number of the publication. The abbreviations used in this bibliography will be found in the early issues of "Experimental Wireless."

I.—TRANSMISSION.

Emission sur Ondes Courtes par Antennes Dirigées.—H. Chireix (*R. Elec.*, 5, 64).

Essais d'Emission et de Réception sur Ondes de 35 Metres.—A. Vuibert (*Onde Elec.*, 31).

Third Harmonic Transmission.—F. D. Bliley. (*Q.S.T.*, 8, 1).

Fixed Condensers for Sending Sets.—H. F. Mason (*Q.S.T.*, 8, 1).

Telephony and C.W. Transmitters for 100 Metres.—G. E. Alinvalla, A.C.G.I. (*Exp. W.*, 1, 11).

Notes on Systems of Modulation Employed in Radio Telephony.—H. S. Walker (*Exp. W.*, 1, 11).

The Poulsen Arc.—D. G. Bower (*Exp. W.*, 1, 11).

Rundfunksender. —W. Schäffer (*Telefunken-Zeitung*, 37).

II.—RECEPTION.

La Réception à la Station de Sambeek.—N Koomans (*R. Elec.*, 5, 64).

Les Amplificateurs à Résistances pour Basse Fréquence.—L. Brillouin (*R. Elec.*, 5, 64).

Générateur-Amplificateur Sans Lampe.—I. Podliasky (*R. Elec.*, 5, 64).

More About Crystal Reception.—F. M. Colebrook, B.Sc. (*W. World*, 258).

Loud-Speaker Horn Design.—H. J. Round, M.C. (*W. World*, 258).

Coil Design for Crystal Reception.—F. M. Colebrook, B.Sc. (*W. World*, 259 and 260).

Étude Expérimentale de quelques Procédes de Détection des Oscillations de Haute Fréquence.—R. Dubois (*Onde Elec.*, 31).

A One-Control Neutrodyne.—J. L. McLaughlin (*Q.S.T.*, 8, 1).

Building Superheterodynes that Work.—(*Q.S.T.*, 8, 1).

The Prevention of Radiation from a Radio Receiver.—Dr. L. M. Hull (*Q.S.T.*, 8, 1).

Receiving Aerials of Low Resistance.—N. W. McLachlan, D.Sc. (*Exp. W.*, 1, 11).

Telephony Reception.—H. J. Neill (*Exp. W.*, 1, 11).

Transatlantischer Rahmen-Schreibempfang.—O. Schade. (*Jahrb. d. Drahtl. Tel.*, 23, 4-5).

Long Distance Radio Receiving Measurements at the Bureau of Standards in 1923.—L. W. Austin (*Proc. I.R.E.*, 12, 4).

The Marconi Four-Electrode Tube and its Circuit.—H. de A. Donisthorpe (*Proc. I.R.E.*, 12, 4).

The Performance and Theory of Loud-Speaker Horns.—A. N. Goldsmith and J. P. Minton (*Proc. I.R.E.*, 12, 4).

III.—MEASUREMENT AND CALIBRATION.

Methods of Wavemeter Calibration.—Maurice Buchbinder (*W. Age*, 11, 11).

A Résumé of Modern Methods of Signal Measurement.—J. Hollingworth (*W. World*, 258, 259 and 260).

Plotting Valve Curves Automatically.—W. Baggally (*W. World*, 259).

An Accurate Wavemeter.—E. L. White (*Q.S.T.*, 8, 1).

Uber ein Empfindliches Röhrenvoltmeter fur Kleine Wechselspannungen.—L. Bergmann (*Telefunken-Zeitung*, 37).

IV.—THEORY AND CALCULATION.

Theory of Thermionics.—H. A. Wilson (*Phys. Rev.*, 24, 1).

On the Calculation of Inductances and Capacities for Multi-Range Tuned Circuits. —J. Erskine-Murray (*Proc. I.R.E.*, 12, 4).

V.—GENERAL.

Sound in its Relation to Radio.—John P. Minton, Ph.D. (*W. Age*, 11, 11).

Building a Rectifier.—(*W. World*, 260).

Etablissement des Avant-Projets d'Emetteurs à Triodes.—Lieut.-Blanchard (*Onde Elec.*, 31).

More About Low Loss Coils.—(*Q.S.T.*, 8, 1).

A Simple Rotary Rectifier.—A. Butement (*Exp. W.*, 1, 11).

Some Experiments with Electrolytic Rectifiers at High Periodicities.—E. H. Robinson (*Exp. W.*, 1, 11).

The Effect of the Earth in the Transmission of Electromagnetic Waves in Radio-Telegraphy.—Prof. G. W. O. Howe (*Electn.*, 2412).

The Energy of Atmospherics.—T. L. Eckersley (*Electn.*, 2412).

Some Radio Direction—Finding Observations on Ship and Shore Transmitting Stations.—R. L. Smith-Rose, Ph.D. (*J. Inst. Elec. Eng.*, 62, 332.)

Method of Producing a Square Wave of Radio Frequency.—J. L. Bowman (*Phys. Rev.*, 24, 1).

Experimentelle Untersuchungen über Schwingungskreise mit Eisenkernspulen.—L. Casper, K. Hubmann and J. Zenneck (*Jahrb. d. drahtl. Tel.*, 23, 4-5).

Wellentelegraphie und Vorgänge in der Atmosphäre.—K. Stoye (*Jahrb. d. drahtl. Tel.*, 23, 6).

Distribution of Radio Waves from Broadcasting Stations over City Districts.—R. Bown and G. D. Gillett (*Proc. I.R.E.*, 12, 4).

The Limit of Regeneration.—N. C. Little (*Proc. I.R.E.*, 12, 4).

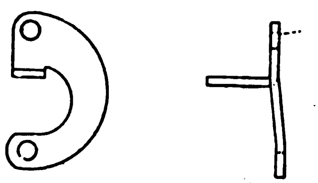
Some Recent Patents.

The following notes on interesting new wireless inventions are supplied by Mr. Eric Potter, Patent Agent, 27, Chancery Lane, W.C.2.

STERLING TELEPHONE MAGNETS.

(*Application date, February* 19, 1923.)

The Sterling Telephone Co. patent a particularly neat magnet for telephone receivers under No. 215,850. There are two identical stampings, each having a portion bent at right angles which

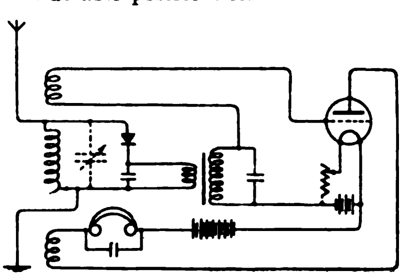


constitutes the pole-piece. The yokes extend over more than a semi-circle, and are bent in their length to the extent of their thickness, so that they overlap, and can both be fixed by the same screws.

REFLEX RECEIVERS.

(*Application date, November* 10, 1922.)

In Patent No. 215,799, Mr. J. Scott Taggart and the Radio Communication Company cover various dual amplification circuits. The first of them, Fig. 1 of the specification, is distinctly interesting, although it is not quite a reflex circuit in the usual sense of the word. In the main, it is a circuit comprising a crystal detector and one low frequency valve, but the main defect of such a circuit in respect of strength of signals—absence of reaction—is got over by providing the L.F. valve with input and output coils, both of which are coupled to the aerial. This circuit appears to have considerable possibilities.

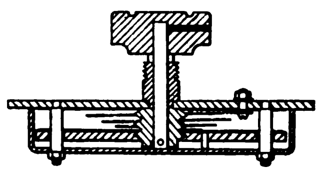


The second diagram in the specification is an ordinary dual amplification circuit with reaction and using a crystal detector, and we really cannot understand its inclusion in any modern specification. The diagram No. 3 is substantially that of Fig. 1 with an H.F. valve in front of the detector, and should have all the advantages of that already described with the addition that, with care in use, it should not cause any interference by radiation.

NEW TYPE VARIABLE CONDENSER.

(*Application date, March* 22, 1923.)

Mr. A. E. Chapman, who may perhaps be known to our readers through his previous inventions, such as the 3 E.V.C. condenser, Filtron grid-leak, etc., covers in Patent 215,906 a new type of variable

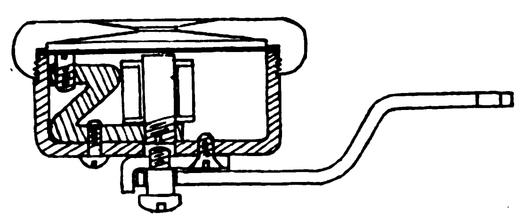


condenser which will be exceedingly compact. The sketch herewith makes the construction so clear that there is hardly any necessity for us to describe it. It would seem likely that this condenser would have the advantage of giving a nice open scale over the whole of its range, especially if care is taken in the design of the spiral plate.

TELEPHONE EAR-PIECE CONSTRUCTIONS.

(*Application date, May* 28, 1923.)

In Patent No. 215,973, J. W. Hobley covers the construction of what he claims to be a simple and efficient type of ear-piece. The distinguishing point is the "Z"-shaped permanent magnet. The receiver is of the single-pole type, one end of the "Z" making contact with the central pole carrying



the coil, while the other end carries an adjustable screw which makes contact with the diaphragm. The construction is shown clearly in our drawing. A separate claim is made that the particular design of cap shown is more comfortable to the ear than other designs.

CAPACITY AERIALS.

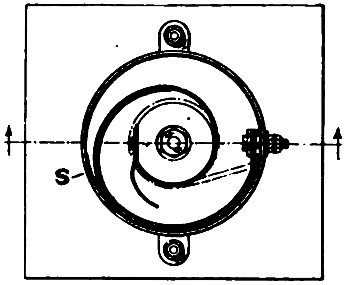
(*Application date, March* 12, 1923.)

In Patent No. 216,247, J. C. Round tries to cover the use of what have usually been known as capacity aerials, consisting simply of a single metal plate elevated. It would appear that the patent is not likely to be valid.

COILED PLATE CONDENSERS.

(*Application date, October* 5, 1923.)

The Telephone Manufacturing Company are responsible for an improvement in coiled plate condensers, one of the chief points of interest being the non-resilience of the flexible plate.

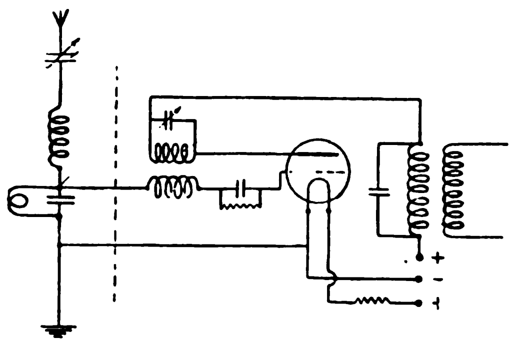


In other respects the construction represents little departure from earlier patents, a spring as at S being utilised for keeping the plate in close proximity to the outer wall as it is unwound. Patent No. 216,038 has just been granted for this invention.

HETERODYNE RECEPTION.

(*Application date, April* 30, 1923.)

To prevent oscillations generated by the local detector valve of a heretodyne receiving system from being impressed on the aerial, it is proposed to use a grid circuit such as that in the drawing, so sharply tuned to the incoming waves that it offers a high impedance to them (so that they are impressed on the grid) while at the same time offering only



a small impedance to the local oscillations, which are of a different wave-length. For this purpose the capacity-inductance ratio is made large and the ohmic resistance very low. As an alternative the grid circuit may be coupled to the aerial.

The inventor in this scheme is Mr. T. H. Kinman of the Royal Aircraft Establishment, to whom Patent No. 216,308 has just been granted.

METAL PANELS.

(*Application date, March* 10, 1923.)

The general principle of construction of the well-known Sterling broadcast sets is covered in Patent No. 216,246 to the Sterling Company and Mr. T. D. Ward-Miller. This, as is well known, consists mainly in the employment of a metal panel instead of the more usual ebonite or other insulating material. Various details of the construction are given in the specification, but the most interesting point is the first claim, which reads as follows: "Apparatus for wireless telephony or telegraphy comprising a box cabinet or like enclosure, a metal deck completing said enclosure, and tuning devices or like components supported directly or indirectly upon the said deck and having their handles projecting through it."

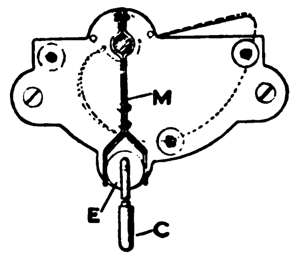
It appears to us that the validity of this claim is really open to question.

FINE CONDENSER ADJUSTMENT.

(*Convention date* (*U.S.A.*) *November* 28, 1922.)

Simple means for providing fine adjustment of condensers of the usual air dielectric type forms the subject of Patent No. 207,797 to Mr. L. A. Hammarlund of U.S.A.

In addition to the usual knob for rotating the movable plates a fine adjustment control is provided at C. Rotation of C produces displacement of



the lever M through the medium of eccentric E. This member M is in frictional engagement with the shaft carrying the moving plates, so that operation of C produces a small angular movement of the plates.

Apart from its simplicity, a material advantage of the construction resides in the ability to locate the fine control outside the immediate sphere of electrical influence.

HIGH TENSION CONDENSERS.

(*Convention date* (*U.S.A.*), *October* 25, 1923.)

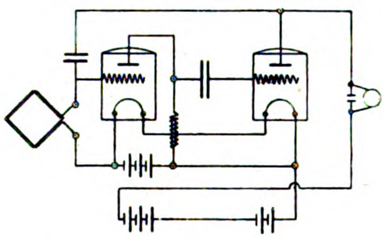
An interesting point in the design of condensers for high voltages is dealt with in Patent No. 206,107 to W. Dubilier. It has been realised of late years by the designers of insulators for the extremely high voltages now used in commerce, that one of the main reasons why, for example, a layer of mica 1/10 in. thick has not ten times the dielectric strength of a layer 1/100 in. thick, is that when the dielectric is subjected to a high voltage, as in the case of a condenser, the electric stress is not equal at all points of the thickness, *i.e.*, the voltage drop between the plates does not follow a straight line law. The consequence is that some parts of the dielectric are more severely stressed than others and may fail. The usual means adopted for getting over this difficulty in the design of high voltage insulators is to divide the dielectric into many layers by placing metal plates between the layers. This, in effect, converts the whole condenser into a

set of condensers in series, and if the areas of the various metal plates are alike the voltage drops over the separate layers of dielectric will be equal to one another. This principle was first utilised in the well-known condenser bushings for high-tension insulators. Its application to the case of condensers is covered by Mr. Dubilier in his Patent.

SEALED RECEIVING SETS.

(*Convention date* (*Germany*) *August* 8, 1923.)

A rather interesting design which we fear would not greatly appeal to the advanced experimenters of this country is that covered by Patent No. 202,978 of the Funktechnische Gesellschaft, m.b.H, an Austrian Company. The set is designed to make any adjustment absolutely impossible. The



aerial is a frame, and is wound round between the inside and outside shells of a double case so that it is quite ungetatable. The two valves and all connections, except the battery plug, are all within the cabinet, which is of itself sealed up. It is interesting to note the peculiar wiring diagram employed. No particulars as to the operation of a set connected in this manner are given in the specification.

AN S.-T. CIRCUIT.

(*Application date, November* 10, 1922.)

An S.-T. circuit forms the subject of Patent No. 215,798 to Mr. J. Scott Taggart and the Radio Communication Co. The principal feature consists in arranging the valves, say one H.F. and one detector, so that the output of the detector reacts both with the input of the detector and the input of the H.F. valve.

The coupling between the coils should, of course, be variable and it would seem that very fine adjustment will be a distinct advantage.

In the Specification several modifications are described at length.

ELECTROLYTIC CONDENSERS.

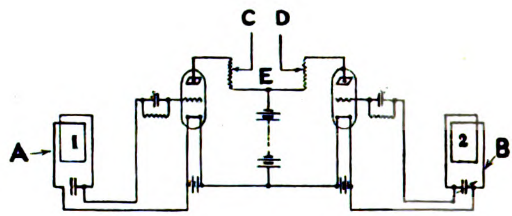
(*Application date, March* 14, 1923.)

Mr. T. F. Wall adds to his earlier specification (215,129) dealing with electrolytic condensers in which the electrodes are of varying oxides of lead, some fresh details covered under Patent No. 215,897. In this latter specification he states that these oxides of lead are sensitive to the chemical changes involved when the condenser is in operation. To ensure their retaining their characteristic properties without deterioration, he now proposes to add a certain amount of oxidising substance to the electrolyte, and states that nitric acid is found to be a suitable agent. He, therefore, adds a small amount of it to dilute sulphuric acid normally used.

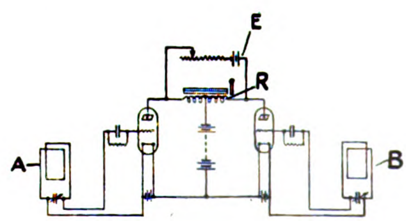
TELEGRAPHIC RECEPTION.

(*Convention Date* (*France*), *August* 24, 1922.)

The Société Française Radio-Electrique give some most interesting circuits for telegraphic reception, with particular application to cases where the messages are to be recorded. All the circuits mentioned in the specification (which is No. 202,998) are based on reception from stations which send out a spacing as well as marking wave, and the general idea is not only to use the marking wave to give a deflection of the indicating instrument in one direction as usual, but also to make the



spacing wave give a negative deflection. This can be accomplished by a circuit of the type shown in Fig. 1, where the two frame aerials A and B with their associated receiving sets are tuned to the marking and spacing waves respectively. It is obvious that the voltage between the points C and D will be twice as great as if only set A were in use and the indicating instruments were connected to C and E. The essential point of the present patent is the application of this arrangement to work with relays. Our second diagram shows the corresponding modifications in the circuit. It will be seen that the anode resistances of the previous circuit are now replaced by the relay R with two windings. The steady current from the battery E traverses the relay and cancels out the field produced by the spacing wave in aerial B. It is obvious that when there



is neither marking nor spacing wave, there will be a certain definite pulling force on the armature of the relay, due to the current from E. When the set A is energised by the arrival of the marking wave, this force will be further increased, so that the sensitivity of the whole installation is very high; further, in so far as atmospherics may be considered to affect both sets A and B alike, they will not produce any effect on the relay. Various modifications are shown on the specification, including its application to telephony.